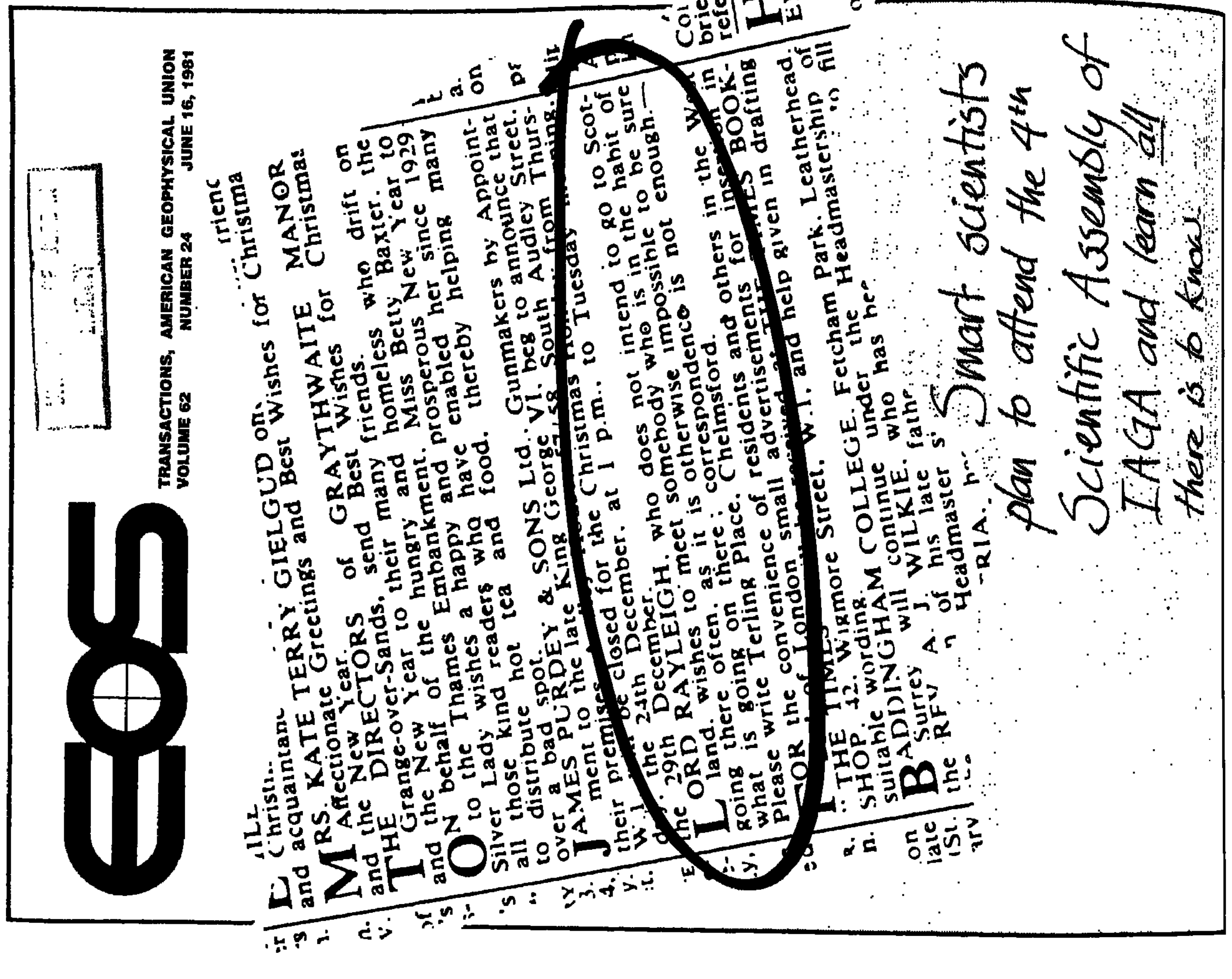

Particles and Fields—Ionosphere

5510 Auroral Zone magnetic effects
SIMULTANEOUS OBSERVATIONS OF AURORAL ZONE ELECTRODYNAMICS BY TWO SATELLITES: EVIDENCE FOR HEIGHT VARIATIONS IN THE TOPSIDE IONOSPHERE
F.J. Rich (Regis College, Weston, MA 02193)
C.A. Cattell, M.C. Kelley, W.J. Burke

The S3-2 and S3-3 satellites were launched into orbits with identical inclinations but with apogees of 1500 and 8000 km, respectively. Both satellites were equipped to measure magnetic fields, electric fields and energetic electrons. By comparing a few cases when the satellites were crossing the auroral zone at approximately the same universal time and location, altitude variations in the electrodynamics of the auroral zone can be separated from universal and local time variations. Such comparisons show that there are times when the field-aligned current per unit of flux in the auroral zone measured by magnetic field deflections at the two satellites is the same at both altitudes. There are also times when the field-aligned current per unit of flux is larger at high altitudes than at low altitudes. This requires flow and currents perpendicular to the magnetic field. Comparisons of the convection electric field (scale size > 0.1°) at the two altitudes show that the electric field does not always map as though field lines were equipotentials. In addition, intense, small-scale (< 0.1°) electric fields perpendicular to the magnetic field, previously associated with electrostatic shocks, which are observed at high altitudes are usually not seen in simultaneous low altitude observations. Only in one of the six passes was there a simultaneous observation of a region of intense, small-scale electric fields variations at 800 km and 1000 km. (Field Aligned Currents, Auroral Zone, Electrostatic Shocks)
J. Geophys. Res., Blue, Paper 1A0761

5519 Interactions between waves and particles
FORMATION OF A CONICAL DISTRIBUTION AND INTENSE ION HEATING IN THE PRESENCE OF HYDROGEN CYCLOTRON WAVES
[illegible]

RPA are presented for the Venus nightside ionosphere. The observed integral electron flux is relatively constant with time and altitude. The simultaneously measured plasma density is much more variable and not correlated with the electron flux. For a typical electron spectrum the ionization rates and the ion density height profiles for O^+ and O_2^+ are calculated for 10 and 90 degrees magnetic dip angle. The O^+ and O_2^+ ion density height profiles are also calculated for a downward flux of O^+ ions at 10, 30, and 90 degrees magnetic dip angle. Comparison of the numerical modeling results with median profiles of O^+ and O_2^+ ions measured by the RPA reveals that a downward flux of O^+ ions of between 1 and 2×10^8 cm^{-2} s^{-1} satisfactorily reproduces both the O^+ and O_2^+ measured median nightside density profiles. The typical suprathermal electron spectrum produces an O_2^+ density profile with peak density approximately half that typically observed and produces an O^+ profile which is about an order of magnitude too small. From the evidence presented in this paper, from previous measurements of adequate O^+ transport across the Venus terminator and from interpretation of ion thermal measurements, we conclude that transport of O^+ ions from the dayside ionosphere is responsible for most of the ionization rate required to maintain the nightside ionosphere. Variation in the O^+ transport mechanism is primarily responsible for the large variation of the nightside ionosphere density. Suprathermal electrons provide a relatively constant ionization rate which is of the order of one-fourth that of O^+ transport and which contributes principally to the O_2^+ peak. (Venus, electron precipitation, ionosphere, maintenance, plasma convection)
J. Geophys. Res., Blue, Paper 1A0891

5545 Ionospheric disturbances
GRAVITY WAVE INITIATION OF EQUATORIAL SPREAD F: A CASE STUDY
R.C. Kelley, M.F. Larsen (School of Electrical Engineering, Cornell University, Ithaca, NY 14853), C. LaHoz, and J.P. McClure
[illegible]

5546 Ionospheric disturbances
REVIEW OF RECENT PROGRESS IN IONOSPHERIC PREDICTIONS
K. Davies (NOAA/ERL/Space Environment Laboratory, Boulder, CO. 80303

This paper reviews the state of ionospheric predictions following the Solar-Terrestrial Predictions Workshop held in April 1979 at Boulder. The review includes: the various uses of the ionosphere, the physical bases, long-term and short-term variations, the techniques used for their prediction and the current state-of-the-art of ionospheric predictions. The different requirements of various users (system designers and planners) are discussed together with the needs for timely dissemination systems.

Because ionospheric predictions and forecasts have been underway for many years, the advances have been of second order. The main advances include the incorporation of features; such as the auroral oval, the magnetospheric cleft, the mid-latitude trough, etc; the positions of which vary with local time and solar-terrestrial activity. Other advances include: four-dimensional models of the ionosphere, which yield electron density profiles useful in raytracing; some new methods for predicting E-layer and E_s-layer characteristics; transionospheric propagation, which requires prediction of total electron content; and scintillation characteristics. In recent years, advances have been made in the use of empirical and physical models of the ionosphere.

Short-term ionospheric forecasting has also progressed in recent years primarily through technological advances in data acquisition (e. g. satellite sensors), data processing (computers) and dissemination of information. Nevertheless, solar forecasting -- a vital ingredient of magnetic/ionospheric storm forecasting -- is still largely an art in which the forecasters' experience and skill, in recognizing and interpreting solar features, plays the dominant role.
Rad. Sci., Paper 1S0758

5563 Plasma motion, convection or circulation
SOME GENERAL CHARACTERISTICS OF UPFLOWING ION BEAMS OVER THE AURORAL ZONE AND THEIR RELATIONSHIP TO AURORAL ELECTRONS
H. L. Collin (University of Southampton, Southampton, United Kingdom), R. D. Sharp, E. G. Shelley, and R. G. Johnson
[illegible]

5540 Ion densities and temperatures
[illegible]

Earthquake Seismograph Development: A Modern History—Part 2

Ben S. Melton

Introduction

Part 1 of this history covered the development of earthquake-type seismometers from 1946 into 1976. Part 2 covers the ancillary amplifiers, recorders, and timing systems which are required for complete observatories and which were developed over about the same time period mentioned. (The figures in this part are numbered continuously from part 1.) It is not immediately obvious how seismometer development depends on creation of appropriate amplifiers, nor how recorder improvement depends on amplifier output power available. Nor is it obvious that timing system design was initiated as an integral part of the observatory and that its functions have been modified as necessary with the advancing art.

For example, the effective sensitivity of Benioff's massive seismometers was limited to the optical magnification provided by a sensitive, low-frequency galvanometer, followed perhaps by magnification of the single trace on photographic film. Multiple traces on that same film could not be accommodated because a strong signal on one trace caused that trace to cross over adjacent traces. Recording of multiple traces required 'stiffer' galvanometers and an entirely new design of photographic recorder; and the less sensitive galvanometers required greater signal power to drive them. The limiting optical aperture also had to be considered. Eventually electronic amplification made possible the design of very small seismometers that could be installed in deep holes, away from local surface disturbances.

Although timing system development is not related to seismometer-amplifier combinations, it relates directly to the recording system and to the filing and recovery of data. Provision of a commercial-frequency power source made practical the use of available synchronous motors to drive recorders at constant speed; crystal frequency control with reference to universal world time allows recording of timing codes related to that time. Magnetic recording now justifies a timing code that permits high-speed automatic search for a specified time.

The Need for a Low-Frequency Seismograph Amplifier

Most modern seismographs use a coil moving in a magnetic field to deliver an electrical output to a galvanometer, the galvanometer consequently deflecting a light beam to make a photographic record. This is a satisfactory arrangement so long as there is no need to view the record before its photographic development. In such cases the galvanometer offers two advantages: It has no inherent 'one-over-f' noise, and its inherent natural period offers a means of filtering, to reduce the seismograph response outside the passband. This includes tidal accelerations and the long-term tilting of the earth's surface, which particularly affects horizontal seismometers. The chief disadvantages of a galvanometer are its reponse to mechanical vibration and its lack of ruggedness, particularly if it has a natural period of tens of seconds. In any case, there is a need for a more flexible system to avoid the photographic process.

At the beginning of the period covered by this history, there were no satisfactory low-frequency electronic amplifiers available, i.e., there were no electronic devices suited to amplifying the microvolt output levels of a seismometer at periods greater than 1 s. Therefore, in order to measure directly and record the seismometer outputs, 'chopper' amplifiers, built by the Perkin-Elmer Company in Glenbrook, Connecticut, were purchased for experimental service. These were called 'D.C. Breaker Amplifiers.' In these amplifiers, a motor drives two switch ('breaker') assemblies on a common shaft: one switch at the input, the other at the output. The switch at the input reverses the low-frequency ('D.C.') signal 150 times a second, and the resulting 75-Hz signal passes through a transformer to a conventional electronic amplifier. The amplified signal goes through another transformer and is rectified by the output switch assembly in order to restore the polarity of the input signal, which can be dc.

Genesis of the Galvanometer-Phototube Amplifier

The D.C. Breaker Amplifier was unsuited for constant field service, and efforts continued to locate or devise a satisfactory substitute. Then, by chance, my attention was directed to a similar need by the U.S. Coast and Geodetic Survey (USC&GS), headquartered in the Department of Commerce building in Washington, D.C. The Aleutian earthquake of April 1, 1946, (magnitude 7.4) caused a tsunami (tidal wave) which rolled across the Pacific and inundated the coastal area of Hawaii, resulting in great destruction of life and property. The USC&GS executive officer then offered to give immediate notification of future large earthquakes—not realizing that most seismographic observatories used photographic records which could not be viewed until after development.

In the Commerce building basement there was a seismometer whose output was used to drive a pen-and-ink recorder in an upstairs hall, for public viewing as earthquakes were recorded. This seismometer drove a conventional galvanometer. A light beam directed onto the galvanometer mirror was focused to a small spot on one edge of a slit, behind which was a photocell. As the galvanometer deflected the spot more or less onto the photocell, its conductivity varied, and the resulting output voltage was amplified by a conventional three-stage vacuum-tube amplifier that employed 1-μF coupling capacitors between stages. The amplifier output was connected to the recorder. The system worked, but coupling capacitor leakage was troubling, and strong input signals sometimes caused the amplifier to 'block' for several seconds.

Tom Pearce of the USC&GS was well aware of the difficulties mentioned and graciously accepted suggestions. I proposed the use of a double-cathode phototube, with the light spot directed so that half would fall on each cathode when the galvanometer was at rest. Then the phototube cathodes could be connected directly to vacuum-tube grids in a balanced (two-channel) amplifier with cathode follower outputs going directly to the recorder, which happened to have balanced driving coils. Such a system could be built without coupling capacitors and would amplify well at low frequencies. Also, as much of the system voltage gain would be in the phototube, the amplifier should not contribute objectionable noise. Such an amplifier circuit was built by Roger M. Wilson and Laurie R. Burgess in late 1949 [see *Wilson and Burgess*, 1952]. However, they cascaded two stages and used two phototubes, one on either side of a pair of mirrors set at right angles to each other. The adjoining mirror edges split the galvanometer light beam to direct the two portions into the phototubes. This system was quite satisfactory, and it established my credibility with Captain Elliott B. Roberts, the USC&GS executive officer—an important factor in the following episode.

By early 1951 the commercial laboratories under Air Force contract had not yet located or devised a satisfactory low-frequency amplifier, so I requested Roger Wilson to build a portable galvanometer-phototube amplifier for demonstration purposes. He gave me a clever arrangement in which the galvanometer signal was generated by a small magnet on the shaft of a clock motor that turned once a second in the field of a coil. The moving light spot from the galvanometer mirror was sensed, as before, by a double-cathode phototube in a bridge circuit, which was amplified by a cathode follower stage. The cathode follower output was biased to deliver alternately plus and minus 3 V, approximately.

Then, to assure ready acceptance of this galvanometer principle, I took this prototype amplifier to a U.S. Signal Corps installation, where a 10-mile line of 'Spiral-4' telephone cable was available. There the amplifier output was connected to a cable pair at one end, and we proceeded to the other end of the line to measure the output. It was, as expected, alternately plus and minus 3 V—a silly, but politically useful, demonstration. This was July 20, 1951.

Richard A. Arnett of Geotech accepted the system in principle soon after my demonstration, and the Model 1450 phototube amplifiers were developed and in field service by November 1952. Figure A (cover) is a view of this amplifier, open to show its construction and controls. It had a balanced (two channel) cathode follower output which 'floated' above ground potential. It continued in field service until 1961. However, in 1956, NBS undertook its evaluation and suggested means of improvement. These suggestions, and a concentrated engineering effort that began in May 1957, resulted in a new design, Model 4300, which went into production in August 1958 together with a separate power supply and filter stage, Model 4304. Controls were simplified and stability greatly improved in this model, which provided a gain of about 100 dB and a dynamic range slightly greater than 70 dB. Its noise level appeared to be limited only by the thermal agitation of its input galvanometer. Figure B (cover) shows this model with its power supply, and Figure C (cover) reveals the arrangement of the galvanometer and other elements in the amplifier case.

In November 1959 the author talked with Hugo Benioff, Frank Press, Walter Ruska, and later with Forest K. Harris of NBS, suggesting that it might be advantageous to design a rugged long-period galvanometer specifically for seismograph use. Harris then undertook such a design, with some suggestions by D. P. Johnson, and the experimental construction and engineering was transferred to Geotech about April 1960. Figure 26 shows this galvanometer and its unusual details. It was incorporated in a long-period phototube amplifier, Model 5240A, shown in Figure 27.

Carrier Amplifiers

Although the galvanometer-phototube amplifiers were satisfactory in most respects, there was continuous pressure from electronic design engineers and others to replace the galvanometer. In part this was justified on the basis of lower costs and greater familiarity with electrical than with mechanical design. It could not be justified on the basis of a lower

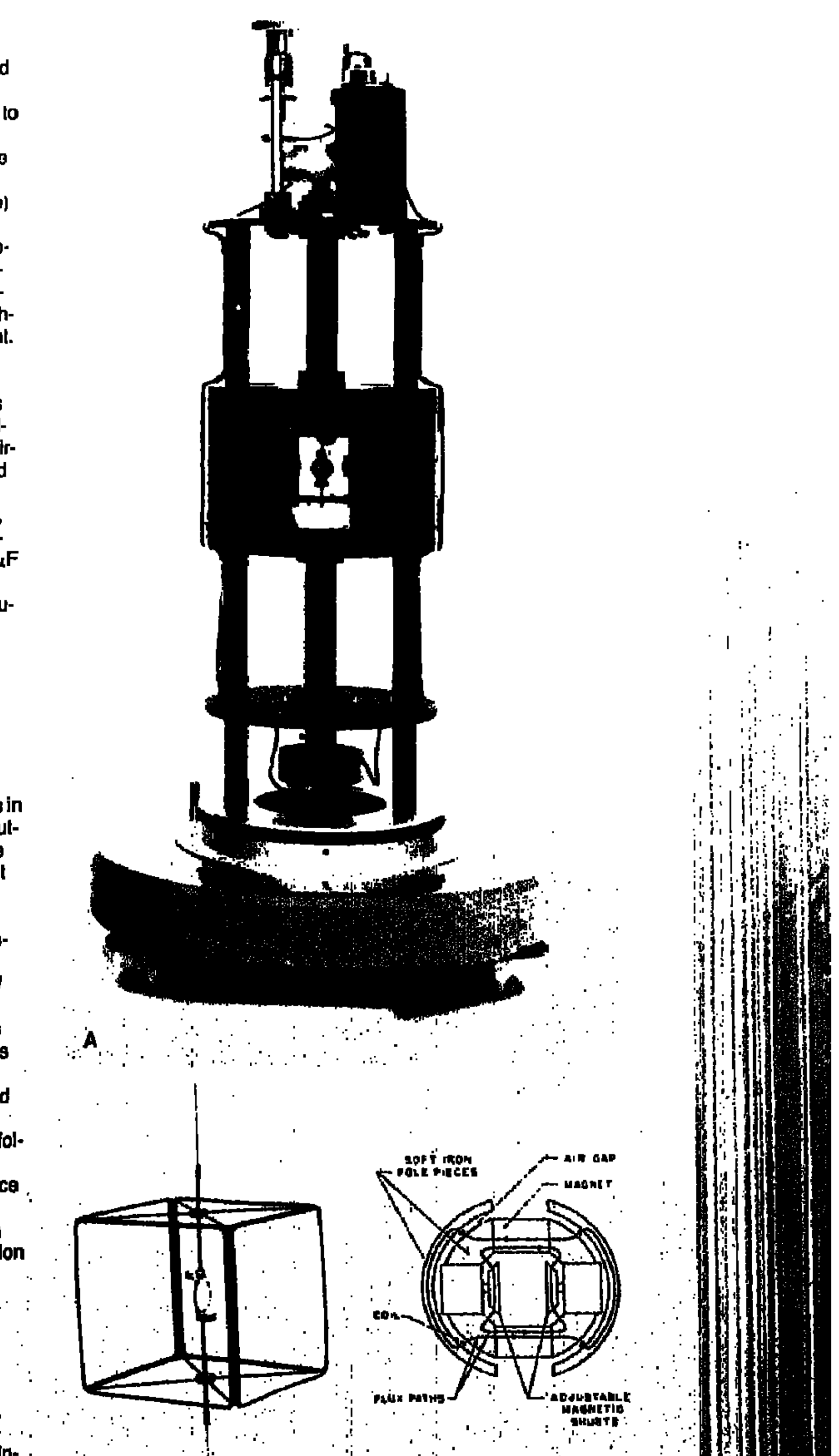

Fig. 26. Long-period galvanometer designed by F. K. Harris: (a) uncased view, (b) coil and mirror structure, (c) cross section of magnetic elements showing flux paths.

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See page 551.

Cover. (A) Model 1450 phototube amplifier with galvanometer in-put. This was the first production phototube amplifier designed for seismograph service. (B) Improved phototube amplifier with separate power supply and output filter. (C) Interior components of the phototube amplifier of (B). The galvanometer appears centered by the knob on the front panel. (For more information, see article by Melton, this page. Part 1 was published in May 26 *EOS*.)

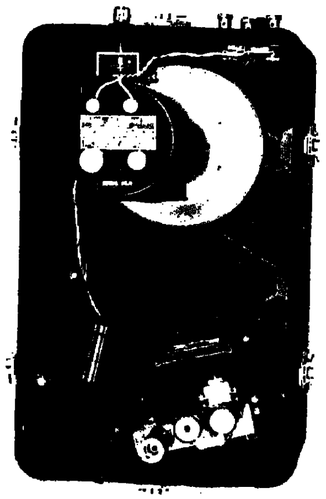

Fig 27. Long-period phototube amplifier that incorporates the Harris galvanometer.

noise level, at least in principle, as thermal agitation noise would be the limit in any case. But the noise that increased with period could be avoided by performing all amplification at high frequencies. In such a system, the low-frequency signal mixes with a high-frequency carrier in some type of modulator, which should not itself inject appreciable noise or distortion. The resulting carrier with sidebands is then amplified and, at a higher power level, demodulated, again with negligible distortion, to recover the low-frequency signal, which can be digitized if desired.

In August 1962, Texas Instruments made available to NBS their new 'reactance' amplifier to be tested and evaluated. Different models of this amplifier bore the designation RA, followed by a model number. The modulator in this amplifier employed a pair of voltage-controlled solid-state capacitances, some diodes, and bias cells. A high-frequency oscillator supplied the capacitance control voltage, so that any low-frequency signal was modulated 'parametrically' to produce a carrier with attendant sidebands. The carrier with sidebands was amplified at high frequency and subsequently demodulated to recover the low-frequency signal. This amplifier was described by its inventor *Biard* [1963] and also by *Davis and Ezell* [1963]. The amplifier was relatively noise-free when connected to an input impedance on the order of 500,000 ohms, but it exhibited input current noise when connected to much lower impedances. There is a practical difficulty in winding a 500,000-ohm coil for a seismometer without obtaining leakage or short circuit between some of the turns. In any case, there remains the thermal agitation noise of the input impedance.

In 1969, ITHACO Inc. of Ithaca, New York, devised a prototype 'chopper' amplifier, Model 6089-74. This amplifier was packaged by Geotech and subsequently used in every channel of the long-period array of symmetrical triaxial seismometers installed in Alaska. In this amplifier the low-frequency signal was chopped at carrier frequency with an electronic switch composed of field-effect transistors. The resulting carrier was amplified, demodulated, and passed through appropriate filters to provide high-frequency cutoff and to limit long-term drift. Essentially this same amplifier was encased by ITHACO and sold as Model 154.

Figure 28, taken from the paper by *Melton* [1976], shows the noise spectra of several amplifiers when connected to different input impedances. All amplifiers tested showed steeply rising noise at long periods, probably originating in stages after demodulation. The phototube amplifier with a 30-s galvanometer shows a hump in the noise response spectrum near the galvanometer period, as expected. The rising spectrum at *shorter* periods was not investigated, but it could be from a parasitic mechanical mode of the galvanometer, the electrical resonance of the coil inductance and distributed capacity, or just the effect of post-galvanometer noise when such noise spectrum is divided by the galvanometer response function (that is, referred to the input).

After the ITHACO amplifiers were put in service on the long-period array channels, it turned out that the chopper switching process put carrier spikes into its broadband carrier amplifier. These spikes 'choked' the carrier amplifier, limiting its gain and therefore the input to post-demodulator stages, causing these stages to show their long-period noise. In view of this field experience, O. D. Starkey designed an amplifier in which the carrier stages were limited to a very narrow band so that any switching transients would be suppressed. This amplifier, Geotech Subassembly 33330, eventually replaced the ITHACO amplifiers in the symmetrical triaxial array. The amplifier's long-period noise at 100 s was less than 4 dB above its input thermal noise level. Its noise response spectrum appears in Figure 8 of Melton's paper.

The above carrier-type amplifiers were designed to accept a low-frequency electrical signal; but if the basic requirement is altered, i.e., made to sense displacement of a seismometer mass, the modulation function can be performed in a varying capacitor attached to the mass and frame. This has been done in various seismometers in the past, including the DTMB and NOL seismometers discussed in part 1. It is a most important feature of the Geotech Model 36000 seismometer and will undoubtedly be a feature of many future designs, perhaps even displacing the electrodynamic system. However, this change has many ramifications, not the least of which is the increased dynamic range and resolution requirement.

Preferred Forms of Seismograph Records

The art of seismology depends upon visual interpretation of seismograph records by experienced seismologists. In this connection, magnetic tape is useless, columns of figures even more useless, and computer analysis is questioned unless it agrees with the seismologist's interpretation. Therefore, the *final form* of recording should be tailored to a human's visual appreciation, in the broadest sense. If for valid reasons part of a seismograph system employs magnetic tape or digital processing, the final presentation, even on a cathode ray oscillograph, should be in a form for human perception.

The earliest form of visible seismograph record was made by mechanical seismographs, which usually had lever systems to magnify the motion of the heavy mass with respect to the instrument frame; the lever system terminated in a scriber that rested on smoked paper which was pulled along to provide a relative time axis. This recording system had a considerable dynamic range, perhaps 60 dB, if the ratio of scribed line to maximum amplitude is the measure. Photographic traces seldom showed this much resolution, but they could be produced by galvanometers in the more flexible electrodynamic systems. We now follow the development of recording systems.

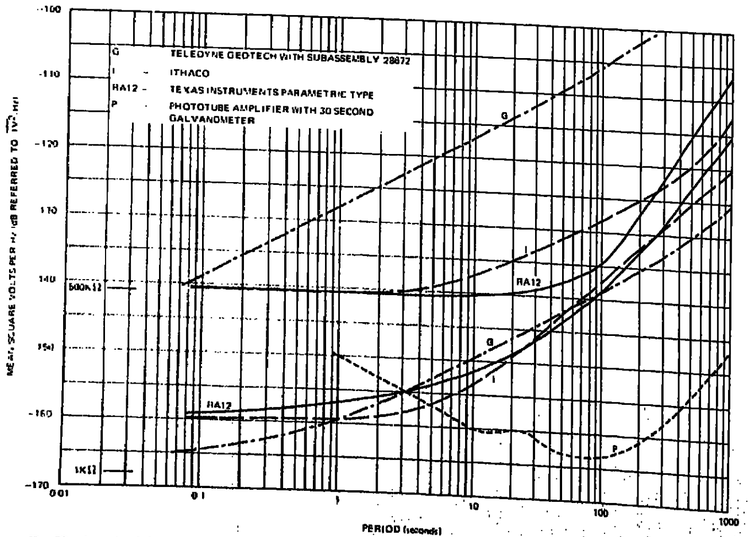

Fig. 28. Smoothed observations of noise density spectra for several low-frequency amplifiers. Upper group of curves was obtained with 500 kΩ input resistance. Lower group was obtained with 1 kΩ input resistance.

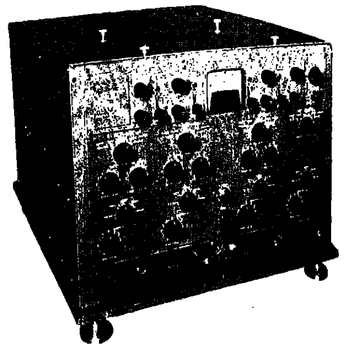

Fig. 29. Photographic recorder for direct optical recording of galvanometer traces on 35-mm film strips. This recorder could remain in a lighted area except when the film strips were being replaced.

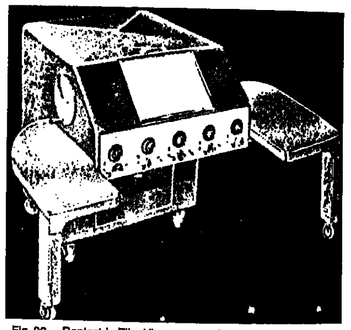

Fig. 30. Pentastrip Film Viewer, manufactured by American Instrument Company.

Early Photographic Records and Recorders

Early photographic seismological records were of two forms: sensitized paper and 35-mm film. The paper strips were about 30 cm wide and 97 cm long. Such strips were wrapped around a drum having a 90-cm circumference. As the drum rotated once every 15 min, a time scale of 1 mm/s was provided. On such a scale, microseisms show clearly when the system has good sensitivity. If the drum is translated along its axis 3 mm per revolution, a 24-hour record can be accommodated on the single paper strip.

The USC&GS recorders were designed to use 35-mm film on narrow drums having 90-cm circumferences. Single drums were only wide enough to accommodate one film strip, but several drums could be in one recorder. The photographic trace was usually much finer on the film than on the paper record. Conventionally, the drums rotated twice an hour, providing a time scale of 0.5 mm/s. The recorder drums were not enclosed, so the recorder was operated in a dark room. These recorders were equipped with galvanometers that were sufficiently sensitive to be driven directly from the seismometers.

A similar recorder, Geotech Model 1301A, was built in a light-tight case, by using a Benioff design. This recorder used 5-Hz galvanometers for direct connection to seismometers and a 20-Hz galvanometer to be driven from a radio time receiver output. The drums carried 35-mm film strips, just as in the USC&GS recorders. The drums were translated 0.795 mm per revolution to provide spacing of the recorded trace on successive revolutions. Time marks were made on each trace by an electromagnetic device which changed the angular position of a small mirror in the light beam, thereby causing the seismic trace to be deflected momentarily. Figure 29 shows this recorder, which was in service early in 1953.

Two such recorders were normally used, as follows: One recorder accepted the signals from four vertical-component seismometers spaced 1 km apart along a line. On this recorder, time marks appeared on the four channels, but the 20-Hz galvanometer providing radio time was omitted. The second recorder carried a signal trace summed from the four vertical-component seismometers, traces from the horizontal north-south component and the east-west component, and a radio time trace. Again, time marks appeared on all four traces, the radio time trace providing any necessary time correction.

Summation of *P* wave outputs of seismometers as much as 3 km apart usually will provide a signal-to-noise improvement, but confidence in the reality of a weak signal is enhanced by comparing individual seismometer outputs. Thus it became important to examine several seismic traces at once in the same time region. Also, optical projection to a larger image of each trace was desirable. Accordingly, a multiple-drum projector was designed and built in 1952 by the American Instrument Company of Silver Spring, Maryland. There were five drums in this projector, each carrying a film strip that was transilluminated by an incandescent lamp. The projected trace images, magnified 10 times, were focused onto a translucent screen in front of an operator's position, the images being brought close together on the screen for easy comparison. Each drum could be rotated and lighted independently, or all drums could be rotated together by a hand crank coupled by independent clutches to each drum. Figure 30 shows this device, called a Pentastrip Film Viewer.

Although this viewer was well designed for its purpose at the time, it remained obvious that there would be a great advantage if the traces from all seismometers in an installation could be recorded side-by-side on the same film strip. But 8 to 12 hours of a single trace filled one film strip, which could not be viewed until after development. There seemed to be no simple change that would lead to a better system. However, some unrelated events suggested an advance. 'Correlation' processes were much discussed in the literature at this time. Upon seeking a practical means of performing the correlation process on more than two signals, I asked NBS mathematician Chester Page to confirm some intuitive conclusions about sign (polarity)-matching multiple signals to establish this coherence or a statistical measure of the probability of signal existence in a noisy background. A theoretical study by Philip R. Karr [*Melton and Karr*, 1957] led to the submission of a project to Diamond Ordnance Fuze Laboratories (DOFL—associated with NBS) to devise a sign-coincidence correlator.

Jacob ('Jack') Rabinow accepted the project for DOFL in late 1951 but persuaded the Eastman Kodak Company (EK) to agree to build the necessary recorder. Ford Tuttle accepted the job for EK because it was in line with the company's basic interest. Thus EK agreed to devise a 16-mm film recorder that would process the film continuously for $10,000, and for an additional $580 to incorporate a viewer into the device ($580 may have been their cost for a standard 16-mm film viewer). In the proposed recorder, small argon lamps would flash to indicate instantaneous polarity agreement, and a high density of the resulting dots on the film would imply coherence of signals among several input channels.

A. W. Tyler and George Breslin began work on the experimental recorder in January 1952, and by March had an operating model in which three small rotating drums carried fluids up onto the sensitized surface of the film that had been exposed to light from the flashing argon lamps. The first drum applied developer solution, the second drum fixer solution, and the third drum wash water. A current of air then dried the film surface. In the completed recorder the film would proceed to the gate of a projector, be transilluminated by a lamp, and imaged through a projector lens onto a viewing screen. By the time this experimental device was operating, I had begun to see that incorporation of galvanometers with an associated optical system into this same recorder would provide for recording and viewing simultaneous signals. Even though there were no acceptable seismic amplifiers available in early 1952, I assumed that such amplifiers could be in service by the time a recorder could be designed for production. In March 1952, I provided Ford Tuttle with a memorandum and accompanying figure to suggest desirable features in the next model recorder. I showed two alternative forms of galvanometer traces, in addition to the dot pattern.

A few months later EK delivered a working model recorder on which eight galvanometer-produced traces were recorded along with the dot patterns from eight inputs, but they did not elect to carry forward the necessary engineering for production. The next contract went to American Instrument Company, which built an experimental model, but that company's management decided that continuation of recorder development would not be as profitable as manufacture of their other

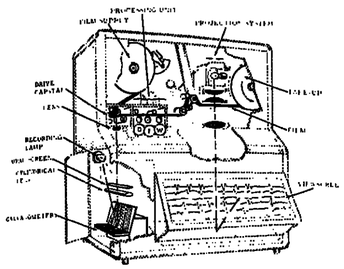

Fig. 31. Diagrammatic outline of Develocorder® functional components.

Fig. 32. Develocorder® in (simulated) operation, showing illuminated record traces. The images appear 10 min after recording of short-period waves, 70 min in the case of long-period recordings. There are only minor differences in appearance of the several models.

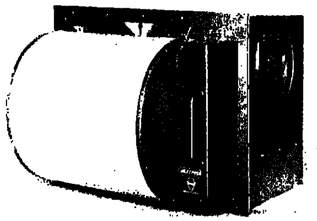

Fig. 33. Film viewer. This viewer accommodates unperforated 16-mm film and displays a x20 magnification of the photographic image.

lines. Geotech was then given a contract for the necessary development and engineering for production. However, the dot pattern record was eliminated because experience showed there was insufficient advantage to be gained by the sign-coincidence correlation for detecting one or two cycles of a weak signal in noise.

A major optical problem with the EK recorder stemmed from its use of individual field lenses for each recording trace. These lenses concentrated the available light from the galvanometer mirrors, and they were a necessary part of the optical system in EK's opinion, but each field lens limited the excursion of the transmitted light beam to the edges of that lens. The result was to limit each film trace to a 'track,' thus preventing the trace from crossing one or more adjacent traces. This imposed a severe, probably unacceptable, limit on dynamic range. To increase light intensity in ways other than through use of a field lens, EK had proposed use of a special ribbon-filament lamp, the filament being imaged in place of a slit. I rejected this change because of future problems envisioned in supplying special lamps.

The individual most immediately concerned with further development and engineering was Jack W. McElwain of Geotech, although many other people and resources were available. The optical problem was solved by use of an 'opal glass' screen in place of the field lenses, plus further attention to optical details, including the galvanometer mirrors. A conventional automobile 12-V lamp (tail light) was eventually used, at reduced voltage, to increase lamp life dramatically. An incandescent lamp life varies inversely as about the 13th power of its applied voltage.

Further development of this recorder, dubbed 'Develocorder®' by Geotech, depended upon details too numerous to describe. One subsystem was the time and date imprint feature, which involved many trials and alterations but which was critically important for referencing purposes. A compromise here was acceptance of numbered days of the year rather than month and date. In an alternative arrangement, a cathode-ray oscillograph screen was imaged on moving film. Figure 31 outlines the functional components of this recorder. The first production models were in service in mid-1958. About 270 have been manufactured, and most of them are still in service.

Develocorders® have been manufactured in three versions: a 16-channel short-period, a 20-channel short-period, and a 20-channel long-period model, all looking essentially like in Figure 32. The Develocorder® that records a cathode-ray oscilloscope screen appears the same but is mounted on a cabinet which encloses the oscilloscope and its controls. The oscilloscope screen is horizontal, and it is photographed through a chimney in the cabinet top.

Although the Develocorder® provides for continuous inspection of seismograms within a short time after recording, the review and analysis of these records may require some hours. For this reason a film viewer, Figure 33, was designed and put in service in mid-1960. This viewer accommodates reels holding as much as 400 feet of film, although a standard Develocorder® is designed to accept 200-foot rolls. A projector produces a x20 image magnification on a viewing screen, and the film can be moved rapidly or slowly through the projector gate by a motor drive.

One other recorder, useful for instantaneous monitoring of seismograph operation, became available about 1954. This is the 'Helicorder®,' which developed from a very similar device used by Benioff. Benioff introduced the method of scribing a line on a paper covered with a white wax, the scriber having an electrically heated wire tip for the purpose. However, the Benioff recorders were usually in groups of three, the drums being on a long common shaft. When Jack Hamilton wanted to sell similar recorders to the Air Force, we told him that they would not be purchased unless they were modified for standard rack mounting. The final design was a rack-mounted single-drum recorder that could accommodate from one to three scribers and whose drum could be run at various speeds, dependent upon the gears chosen. Figure 34 shows this recorder. An associated amplifier provided adjustable voltage gain and a timing input circuit to make time marks by deflecting the scribe a controlled amount.

The Dry Film Recorder

There have been many investigations and attempts to eliminate the wet chemical processes of the Develocorder®, but none survived preliminary investigation until about 1972, when Burnard Kirkpatrick of Geotech was given support to devise a system around a '3M' (Minnesota Mining and Manufacturing) dry film process. Kirkpatrick and others created a recorder in which a laser beam burned off the emulsion from 16-mm 3M film selectively. The beam was gated on and off by an electrooptic (pockels cell) shutter while scanning across the film. This put a microscopic hole in the emulsion each time the electrooptic shutter allowed the beam to pass. The completed engineering prototype, Model 36100, Figure 35, provided all of the features of the Develocorder® and also accepted the output of a typewriter keyboard for record identification purposes. It was sold to the Air Force in 1974 but never carried into production because of the high costs ($100,000) of necessary documentation and a very uncertain commercial market. Technically, it appeared to be a satisfactory device.

Timing Systems

If we assume that compressive body waves (*P* waves) are to be used to locate the focus of an earthquake, we need to know the arrival times of waves from that event at four or more stations. Each time difference between two independent records of the event implies that it occurred along a surface of constant time differences, and the intersection of two such surfaces (minimum of three stations) with the earth's surface defines (in principle) two epicenters; the common intersection of three such surfaces (four stations) defines the focus, or hypocenter.

In order that any of these time differences between stations can be measured, and assuming no communication between stations, their clocks must carry the same time. Before 1950 a pendulum clock at a seismological observatory was equipped with electrical contacts that closed at programed intervals, the minimum interval being 1 min. These clocks were set closely to world time, and their rate was monitored consistently so as to know their error. In 1949, world time observatories were located at Greenwich, England; Paris, France; the U.S. Naval Observatory at Washington, D.C.; and the NBS radio station at Boltsville, Maryland. However, it was difficult to be assured that these observatories kept the same world time within, say, a tenth of a second. They made independent star-transit observations at intervals when weather permitted, but each observatory's zenith direction, if uncorrected, depended on the local gravity vertical. Also, they had to rely on pendulum-controlled clocks ('free-pendulum' Shortt clocks) for carrying the time between observations. Crystal-controlled clocks were still under development and were not trusted.

The Bell Telephone Laboratories were approached to see if they would undertake development of a timing system suited for use by Air Force stations. They declined, but recommended American Time Products (ATP), New York, N.Y., as a competent organization to devise a clock whose basic rate would be controlled by an electrically driven tuning fork. ATP had been building such fork-controlled devices for use in timing watch balance-wheel rates. Also, the broadcast stations kept accurate scheduling time with ATP-driven clocks.

Figure 36 shows the ATP programer designed for the Air Force. In this device, a 240 Hz electrically driven tuning fork in a temperature-controlled oven fed two cascaded multivibrator stages to deliver 60 Hz. A power amplifier provided about 50 W of 60 Hz at a nominal 115 V. Part of this power drove a synchronous clock motor. The motor drove a gear train to actuate switches by means of cams, and the switches were arranged to close a circuit on the following schedule: one 0.3-s pulse every 10 s except on the minute, one 0.5-s pulse every 5 min except on the hour and half hour, one 1.0-s pulse on the half hour, and two 1.0-s pulses, separated by 1 s, on the hour.

The remaining power output was available to drive recorder motors in the seismograph station.

To assure continuous timekeeping in the event of power or electronic failure, pendulum clocks were investigated. This

Fig. 34. Hot stylus visible recorder. The paper used on this recorder has a black surface covered with white wax. An electrically heated stylus scribes a trace by melting the wax. Alternatively, a translucent paper can be used so that removing the wax provides a negative for photographic reproduction.

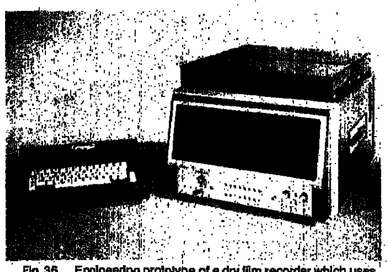

Fig. 35. Engineering prototype of a dry film recorder which uses a controlled laser beam to burn away the surface emulsion of the film.

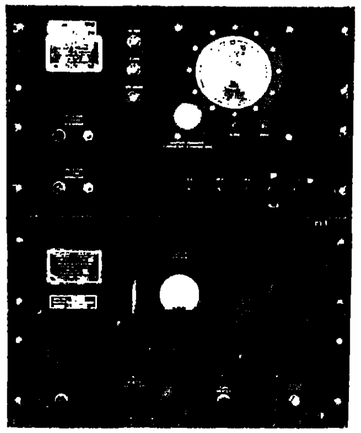

Fig. 36 American Time Products programer. This device had switches mechanically programed by motor-driven gears and cams to provide circuit closures at scheduled time intervals. The circuit closures actuated electrical elements in associated seismographic recorders to put time marks on their records.

resulted in the purchase and use of British-made Synchronome Clocks, to be driven from a separate battery supply. The escapement of this clock provides a contact closure every 30 s, which energizes an electromagnet to give the pendulum a slight push at the bottom of its swing. The pendulum then swings freely until the escapement initiates another electrical impulse. The time rate of this clock is good because its escapement requires very little energy—energy which would damp pendulum oscillations—and because very little energy is used to keep the pendulum swinging. (This clock is actually the slave portion of the two-pendulum Shortt clock used in many time observatories in the 1950's.)

In 1953 the crystal-controlled clock was reconsidered, and Texas Instruments designed a system, Model 100B, which is shown in Figure 37. To attain reliable operation of the crystal-frequency divider chain, only binary dividers were employed to convert the crystal frequency to the 60 Hz desired for operation of clocks and recorders. Unfortunately, this limited the choice of crystals to those whose frequency was a power of 2 multiple of 60 Hz, crystals which were not the standards in multiples of 10.

By the time this system was designed, experience had shown that either the NBS station at Boulder, Colorado, WWV, or WWVH, the NBS station in Hawaii, could be received at nearly all Air Force observatories at some time during any 24-hour period. Therefore, a means of accurate observation of an NBS time signal relative to the local crystal clock time was required. To accomplish this function, a neon lamp was mounted back of a slot in a disk which rotated once a second, the disk being geared so that the slit was at the top exactly on each second pulse of the clock. The neon lamp was triggered on by the WWV time signal on each (world time) second. Then by the relation of the light flash position to the top of the circle covering the disk, the error in fractions of a second could be observed.

Later, investigations disclosed that the crystal-frequency divider transistors were not driven well into saturation, so at higher ambient temperatures one or more stages might lock in an intermediate state, causing timing system failure. Also,

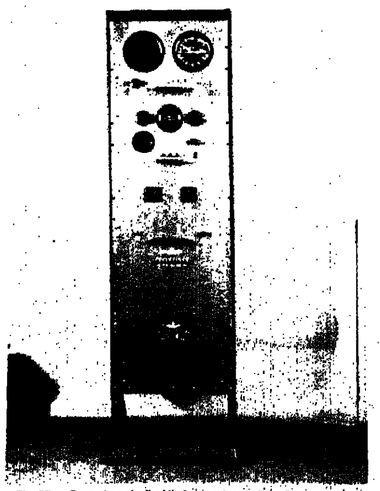

Fig. 37. Crystal-controlled timing system built by Texas Instruments. This system was designed for operation from the ac power line, requiring 325 W at 45 to 60 Hz.

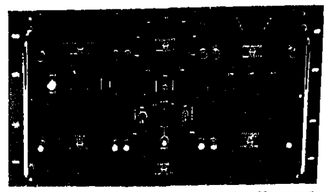

Fig. 38. Modular assembly timing system designed for operation from a storage battery supply, 22 to 28 V dc.

the 60-Hz output tubes overloaded because not all of the primary turns of the output transformer were used, and much of the plate current was required to saturate the core. The corrective action was to use all of the primary. An appropriate secondary tap then raised the output voltage considerably. A step-down transformer and a full-wave rectifier were connected to the output, and the resulting dc was introduced as a grid bias to an earlier stage in the amplifier, thereby lowering and stabilizing the power output voltage, also lowering the plate current of the output tubes. Installation of these 100B systems in air-conditioned areas stopped the erratic failures in the frequency divider.

The need for a semiportable timing system for use by temporary field observatories brought forth the next design, which was put in service in the latter part of 1958. A modular assembly was proposed by James R. Womack of Geotech, with the obvious advantage that a change of functions would not require complete redesign. A tuning fork-divider clock/programer that would deliver a simple sequence of time pulses was planned originally, but claims for a low-cost crystal oscillator with 10^{-7} precision and other desired functions resulted in a more sophisticated design. Figure 38 shows this Geotech Model 5400 system. The upper row of modules, from left to right, are (1) crystal oscillator with control to adjust frequency if necessary, (2) stroboscope to observe relation to WWV time signal to local clock setting, (3) clock and programer to deliver programed output pulses to recorder. The lower modules are (1) power amplifier to deliver precision 60 Hz for recorder drives, (2) input power (24-V dc) distribution and control module with speaker, (3) crystal-frequency divider chain. (The crystal frequency is 60 times the 9th power of 2, or 30,720 Hz, so nine binary counters comprise the frequency divider.) This timing system later became part of the World-Wide Seismograph System, Model 10700. The total network is now known as the Worldwide Standard Seismograph Network.

With the advent of magnetic tape recording, and the attendant necessity of automatic scanning to locate a specific time on the tape, another form of time code was required. Also, long-period recordings needed a somewhat different time mark output than that for short-period records. To satisfy such requirements and to take advantage of later technology, the Geotech Model 19000 system, shown in Figure 39, was

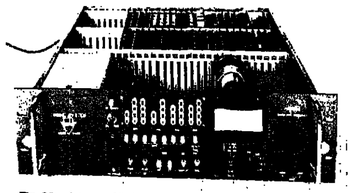

Fig. 39. Improved timing system designed to provide several forms of output codes, including one for magnetic tape recording and automatic scanning.

devised. Better crystal oscillators provided a drift rate of less than one part in 10^9. The function of comparing system time to WWV or WWVH was incorporated in an oscilloscope with three different sweep rates, and also provision was made to heterodyne the crystal oscillator frequency with the received radio signal. The magnetic tape time code conformed to VELA-UNIFORM* specifications. Finally, 100 V-A of frequency-regulated 60-Hz power was provided for driving recorders. These timing systems became available in 1964.

The Model 5400 and the Model 19000 timing systems were designed to operate from a storage battery supply, 22- to 28-V dc, the batteries normally being charged by (rectified) power from a 115-V ac power line. This avoided system outages caused by temporary ac power failure and reduced the importance of having a mechanical clock for backup. The battery supply provided both plus and minus 12 V, which permitted design flexibility in solid-state systems.

Conclusion

The period covered by this history was also the period during which scientific knowledge and engineering technology advanced greatly. At the beginning, little was known about earth noise, its source, or its variation with depth beneath the surface. Pendulum clocks were the most trusted means of timekeeping. Vacuum-tube amplifiers were inadequate at seismic frequencies. Solid-state devices were limited in application and power. Seismic signal transmission was limited to the vicinity of each seismometer. Multichannel recording of seismic arrays was impractical. Immediate observation of seismic records was limited to mechanical seismographs.

*The U.S. Government program to monitor underground nuclear explosions.

Digitization of records for computer processing was slow and laborious. Magnetic tape recording was impossible without the required low-frequency amplifiers.

At the end of the period the data on earth noise had been collated and coordinated. Crystal or atomic clocks were available. Vacuum tubes were nearly obsolete, while solid-state devices had advanced in sophistication and power-handling capacity. The basic theory of seismometers is better understood and has permitted the design of smaller, more useful instruments. Multichannel records are available for quick inspection, and digitization can be near the signal source or elsewhere in the system. The seismologist now has at his disposal some tools which he could scarcely have foreseen, or even appreciated, in 1948. Technological advances after 1975 not covered in this history have altered many processes of handling large quantities of data, but I leave them for others to discuss when enough time will have passed to permit objective assessment of their impact on seismology.

Other than that, there is a growing appreciation of the fact that noise measurements in deep wells in some formations now show a marked decrease of noise with increase of frequency beyond 1 or 2 Hz. This is in a range suited to the use of crystal-pressure accelerometers, wherein the inertia of a mass in contact with the crystal provides an adequate output. Dynamic damping here will prevent crystal oscillation and eliminate loss damping thermal noise, and electronic amplifiers are more easily designed for these frequencies. The result may be sensing capabilities beyond those imagined today.

Acknowledgments

The attentive reader will realize that I have had immeasurable, unstinted assistance in my search for supporting documents, negatives, and unofficial notes. For this, and for use of the typing and reproduction facilities of Teledyne Geotech, I am indebted to Gaston W. Breland, the company president, and to members of his staff. Also, special thanks are due Dennis Recla of the organization, who saved in his personal files many obsolete items and discarded memoranda, making them available to me.

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News

Dallas Peck Selected for USGS

Volcanologist Dallas Peck has been chosen by the Reagan administration to be the next director of the United States Geological Survey (USGS). Peck, chief geologist of the USGS since 1977, is a past president of AGU's section on Volcanology, Geochemistry and Petrology. If the Senate approves Reagan's choice, Peck will become the 11th director of the USGS, succeeding H. William Menard, who resigned in January. Doyle G. Frederick, associate director, has been serving as acting director.

Dallas Peck is highly regarded throughout the Survey. His field studies include notable work in the Cascades of western Oregon, in the Sierra Nevada batholith, and at the Lava Lakes in Hawaii. He has been involved with geological projects in Alaska as well as with numerous studies in the U.S. related to geothermal and volcanic energy sources.

The Geological Survey will benefit from Peck's administrative abilities. He first joined the Survey as a field assistant during the period 1951–53, just after receiving his B.S. in geology from CalTech and while he was completing requirements for the M.S. He then went to Harvard for doctoral studies and rejoined the survey to finish his thesis. The thesis was completed in 1960, and he was awarded the Ph.D. degree. Between 1960 and 1977, Peck followed the customary USGS practice of rotation between field and administrative duties. It is often said that the USGS directors during that period considered his advice, counsel, and services indispensable. He had to fight for his terms in the field, away from Washington.

The USGS has been noted throughout its history for its professional excellence. It would appear that there will be no break in that tradition under Peck's direction.—*PMB*

Mission to Observe Oceans Proposed

Most serious of the obstacles to understanding ocean circulation is the 'absence of any widespread means for observing it,' according to the recent report of the Ocean Topography Experiment (TOPEX) Science Working Group. To overcome this hurdle, the panel recommends a 5-year satellite altimetry experiment to measure the ocean's topography. Aim of the experiment would be to yield a global view of ocean dynamics. A better estimate of the geoid—vital to many geophysicists—would result from TOPEX, the group said. A better understanding of ocean circulation would also aid commerce and shipping, fishing, national defense, and weather prediction. In addition, it could help to evaluate ocean disposal of radioactive wastes.

Oceanographers now rely on ships, buoys, and drifting floats to yield ocean data. These instruments, however, can only chart the ocean for a few months at a time in discrete regions. 'No existing method permits observation on the global scale that is required to measure and understand the ocean as an entity,' the panel reported. Satellite altimetry of the oceans has the 'demonstrated capacity' to observe global ocean circulation, the working group concluded.

Established last year by NASA's Environmental Observation Division, the TOPEX group was charged with assessing the usefulness of satellite measurements of ocean topography. Carl Wunsch of the Massachusetts Institute of Technology chaired the 15-member panel. The Jet Propulsion Laboratory was responsible for conducting the study.

The group recommended that NASA start a 5-year satellite altimetry experiment to measure ocean topography. These measurements would be integrated with subsurface data and models of the ocean's density field to determine the general circulation and variability of the ocean, according to the TOPEX report. Then, scientists could calculate the heat transported by the oceans and the interaction of currents with waves and sea ice. The ability to predict the circulation caused by wind movements also could be tested. The TOPEX group had hoped for initial funding in the fiscal 1983 budget, with launch of the satellite to follow in 1986, Wunsch told *Eos*. It's an unlikely candidate, though, for the fiscal 1983 budget with the present tightening of the fiscal belt, he added.

Why satellite altimetry? The working group emphasized the need for the accuracies obtainable with a TOPEX satellite. These accuracies, the working group said, have been demonstrated with Geos-3 and Seasat. In addition, altimetry does not depend on cloudless skies and good weather; it works under any conditions. Heavy rain may cause difficulty in data interpretation, however.

The working group also pointed to the data interpretation possible with satellite altimetry. The large-scale movement of water in the sea tends to manifest itself as an elevation change of the sea surface proportional to the strength of the surface currents. If the currents are time varying, then too is the surface elevation. In addition, this sea surface variation quantifies the surface pressure of the sea (not atmospheric pressure) directly related, by known equations of motion, to subsurface water movements.—*BTR*

Geophysics at Sea: Rising Fuel Costs

In the past year or two the costs of fuel for research vessels have seriously affected geophysical and oceanographic studies at sea. Many vessels have not left the dock during that period, others have been used sparsely, and research programs have suffered.

The National Science Foundation has considered new efficient vessels to replace the currently existing fleet. New propulsion systems are being considered, although for this decade, no large breakthroughs are expected in the efficiency of diesel engines.

Ten years ago, diesel bunker fuel sold for about 15¢ a gallon. In 1973 the price had tripled to about 45¢. In 1980 the price per gallon had risen to more than one dollar, about 700% increase over the pre-1973 prices! The fuel costs always were a large part of the operation budget of a research ship, so the increases have affected the entire oceanographic community. A small marine engine of approximately 400 horsepower, operating at 75% of its load capacity for a year's use in 1970 cost about $15,000. At a cost of $105,000 in 1980, the engine would be prohibitively costly. Many small to medium research vessels use a separate 1000-horsepower diesel engine for propulsion and for onboard electric power generation. Larger vessels use proportionally more horsepower, but with larger engines comes improved efficiency, a possible key to solving the fuel problem for the 1980's. The engines themselves will probably not improve in efficiency (20% improvement by the 1990's is optimistic), but it is possible that the larger vessels with larger engines will be used more than smaller vessels. The fact that more stations at sea, more instruments, and more project per cruise in large vessels will offer the only practical answer. Oceanographic research budgets are not expected to rise sufficiently to absorb the new costs.—*PMB*

Nation's Water Picture

The nation's water picture improved somewhat in the north central and northeastern United States during May, but below normal water resources conditions persist in the Southeast and parts of the Midwest, according to the U.S. Geological Survey.

USGS hydrologists said May streamflow averaged well below normal—within the lowest 25% of record—at half of the 162 key index stations reporting from across the country. These extreme low flows were reported in all or parts of 33 states and were concentrated in a wide band from Virginia west through Tennessee and south to Florida and Mississippi.

The persistent dry trend was also evident in the combined flow of the nation's 'Big Five' rivers—Mississippi, Columbia, St. Lawrence, Ohio, and Missouri—which averaged 981 billion gallons a day (bgd) during May, 12% below normal. Although combined flow of the Big Five now has averaged below normal for six straight months, flow has begun to show some improvement over past months. The Big Five rivers account for almost half of the stream runoff in the conterminous United States and provide a quick, useful check on the nation's water resources.

Highlights of May Water Conditions

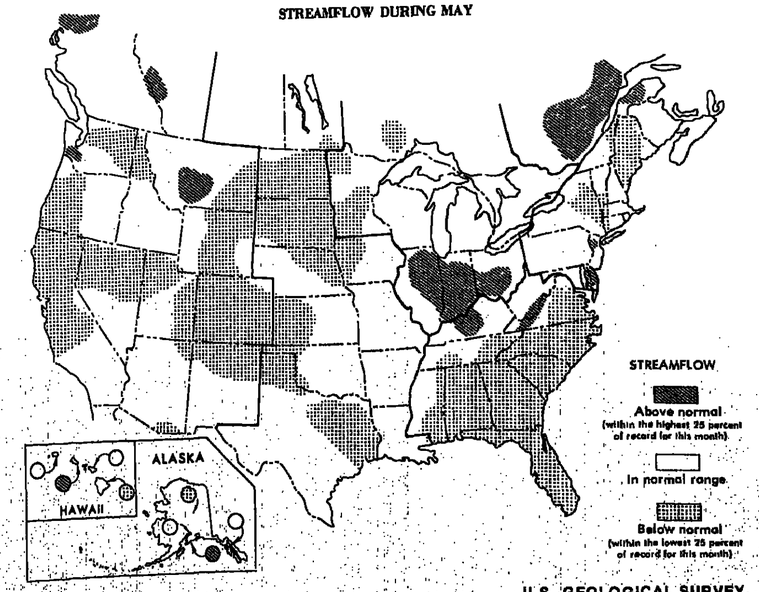
Northeast. Streamflow conditions generally improved throughout the Northeast, with New Jersey and Maryland reporting strong improvement and flows that were above normal at several gaging stations. Some improvement was also noted in the Delaware River Basin.

Southeast. All but three of the 32 index stations reporting from Virginia to Florida were in the lowest 25% of record during May. That is, 75% of the time flows have exceeded those reported during May. New monthly record low flows were established in Virginia, North Carolina, and Georgia. Groundwater levels in most states are below normal for this time of year and, in some areas, are reaching record low levels. Streamflow in North Carolina has been below normal for six straight months.

Great Lakes Region. Streamflow was generally in the normal range throughout the Great Lakes Region, although scattered pockets of low flow were reported in Minnesota, while parts of Ohio, Indiana, and Illinois reported above normal flows.

Midwest. Streamflow in much of the Midwest remains below normal, stretching from North Dakota south to Texas and into the Rocky Mountain states of Colorado, Wyoming, and Utah.

Far West. During May, 11 of the 24 gaging stations reporting from Washington, Oregon, Idaho, Nevada, California, and Arizona reported below normal flows, i.e., within the lowest 25% of record. Streamflow throughout California was below normal for the month, in response to a season of below normal precipitation.



Postdoctoral Fellows: A Diminishing Supply

Highlighting the modern concept of what used to be positions of status are descriptive terms such as the 'perennial postdoc.' The research scientists with now Ph.D. degrees in hand that were awarded postdoctoral fellowships have been likened to 'planes . . . stacked in a holding pattern' (E. M. Looper, *Acad. News Rep., 31*, p. 3, 1981). In the fields of physics, chemistry, and biology a situation of 'extended appointments' for postdocs still exists because of a lack of full-time positions at the Ph.D. level.

The situation in the earth sciences contrasts sharply. Recent hiring patterns by petroleum and mining companies and by the federal government have followed a quickened pace. Geoscientists at the bachelors' and masters' levels are going directly into industry. Graduates in earth science with Ph.D. degrees are accepting research positions in industrial and government laboratories and thus are bypassing the postdoctoral experience. As a consequence, the number of graduate students and postdocs in earth science academic departments has fallen sharply over the past year.

A desirable balance between job offers and available personnel seems to have been lacking. When the total number of postdocs expanded in the 1970's, cutbacks in the space program produced uncertainties in the job market so that postdoctoral appointments, normally 1–2 years, were extended for an additional year or two. Postdocs moved from laboratory to laboratory, resulting in a good deal of frustration; feelings ranged from disappointment to bitterness as postdocs saw the number of permanent job opportunities decrease.

Now the problem is reversed. The award of a postdoctoral fellowship used to be considered prestigious, an unusual opportunity to gain experience and to do some serious research under the auspices of a famous mentor. Aside from the instances where postdocs have been used as 'cheap labor for established investigators' who were trying to meet grant or contract deadlines, the postdoctoral fellowship experience is still considered valuable and essential. The memories of recent bitterness coupled with attractive offers in petroleum and resources have prompted many Ph.D. holders to bypass the postdoc.

If past employment cycles persist, it may not be long before the job market tightens again, producing another increase in postdocs. It is noted, however, that even 'the postdocs caught in the holding pattern are filling vital roles in research.' (*Postdoctoral Appointments and Disappointments*, 429 pp., National Academy Press, Washington, D.C., 1981.) All things considered, the postdoctoral experience is highly beneficial to the Ph.D. holder who is headed for a career in research or in teaching at a research-oriented university. The contributions to science of the postdoc are considered valuable enough that the National Academy of Sciences' Commission on Human Resources now recommends that postdoctoral stipends be raised to be comparable to the average starting salary of an assistant professor. (The average stipend now is 40% less.)—*PMB*

Political Action Committee for Scientists

Spurred by budget proposals that could severely reduce science funding (*Eos*, March 24, March 3, February 10), seven scientists currently serving as Congressional Science or State Department Fellows recently founded a political action committee (PAC) for scientists. The Science and Technology Political Action Committee (SCITEC-PAC) aims to make scientists more politically aware and better informed about potential legislative actions that affect research. It will also serve to 'establish a political presence' with respect to science, said Donald Stein, SCITEC-PAC's chairman.

The organization is not a lobbying group, explained Stein, professor of neurology and psychology at Clark University and the University of Massachusetts Medical Center. 'Lobbyists seek to influence officials by presenting information to them,' he said, 'while a PAC tries to influence the outcome of elections through campaign contributions of money, time, and effort in behalf of candidates that share similar goals and aspirations.' In other words, the PAC will be a vehicle for promoting candidates for federal office who advocate strong support for scientific research and training. In addition, the PAC will develop and study science policy and budget issues and will attempt to stimulate government and private sector interest in these issues.

Scientists are traditionally reluctant to think about political activity as a method for furthering their cause, noted David Garin, SCITEC-PAC treasurer. Nobody ever thinks of scientists as an organized body because they never have been one, Stein added. Scientists can no longer sit back and watch the continuing erosion of federal support of science, he said. Scientists must make their needs known to Congress or else have their passiveness misinterpreted as a lack of concern, Stein said.

The PAC will not compete with scientific societies and their lobby groups, Garin and Stein emphasized. A nonprofit and nonpartisan organization, SCITEC-PAC will not take stands on issues, they said, but will apprise scientists of legislation that affects them.

To start this effort, the organizing committee opened an office at 305 Massachusetts Avenue, N.E., in Washington, D.C. They also are mounting a small fund-raising campaign this summer, to be followed by a larger direct-mail campaign early this fall. Stein says he hopes the organization will have gathered enough momentum to have an impact on the 1982 federal elections.—*BTR*

Langley Medal Awarded

Robert Thomas Jones, senior scientist at the Ames Research Center, Mountain View, Calif., was awarded the distinguished Langley Medal by the Smithsonian Institution for his 'extensive contributions in theoretical aerodynamics, particularly with regard to development of the swept wing, supersonic area rule and, more recently, the oblique wing.' Jones is an internationally acclaimed expert on aerodynamics, optics, and biomechanics as well as an applied mathematician, astronomer, inventor, author, and violin maker.

The Langley award has been given to just 16 recipients since it was established 73 years ago. Past recipients include Wilbur and Orville Wright, Charles Lindbergh, and Richard Byrd. Named for Samuel Pierpont Langley, aeronautical pioneer and third secretary of the Smithsonian, the medal honors 'especially meritorious investigations in the field of aerospace science.'

Jones discovered the theory of the "simple sweepback," one of the most important discoveries in aerodynamics (swept wings are seen on most jet aircraft today). Jones' 1944 discovery of the sweepback theory was not accepted by most scientists at the time, but NACA (later to become NASA) began experiments to test the theory. For his discovery of the sweep effect slender wing theory and other contributions, Jones was given the Sylvanus Albert Reed Award by the Institute of the Aeronautical Sciences in 1946. That same year, he came to work for Ames Research Center.

In 1973, Jones was elected to the National Academy of Engineering and the American Academy of Arts and Sciences. He was honored in 1976 with a cash award from NASA's Inventions and Contributions Board and received the Prandtl Ring Award in 1978 from the German aeronautics Society (Deutsche Gesellschaft fur Luft und Raumfahrt), considered the highest honor in the field of fluid dynamics.

A Fellow of the American Institute of Aeronautics and Astronautics, Jones was chosen as an honorary fellow in 1979. In 1981 he was elected to the National Academy of Sciences.

Earlier this year, Jones was presented the President's Award for Distinguished Federal Civilian Service, in honor of the many contributions of his 40-year government career.—*PMB*

Reagan Names New Science Advisor

On May 19th the White House announced that Los Alamos Scientific Laboratory (LASL) physicist George Keyworth had been chosen for the position of science advisor to President Reagan. Evidently, Keyworth was selected after several other candidates, mostly from industry, had been eliminated from the running. The position of science advisor to President Reagan has been controversial. White House staff memoranda released over the past few months gave hints of the Administration's not wanting to fill the post vacated by geophysicist Frank Press. The 'corporate board structure' planned for the new administration simply did not have a logical place for a scientist with access to the President. After widespread outcries from the scientific community, the decision to eliminate the post of science advisor was reversed, followed by a quick search for a suitable candidate.

There are several new slants to the appointment. First, the decision to fill the post was critical. The science advisor heads up the Office of Science and Technology Policy (OSTP), which initially was to be transferred out of its high-level position at the White House. The exact relationship of the OSTP to the new administration structure remains unclear at this time, but it has been stated that the advisor will have the President's ear and will be involved in the budgeting process at the Office of Management and Budget.

Apparently, the Administration wanted an advisor with knowledge of the defense establishment. Candidates from the corporate world with sufficient stature for the position simply had too large a salary discrepancy (about a factor of 10 difference in salary between industry and government at this level). Keyworth, on the other hand, was supported strongly by Edward Teller and Harold Agnew, former director of Los Alamos, both 'well known for their hawkish views.' (*Science*, May 22, 1981, p. 903).

George Keyworth, B.S. Yale 1963, Ph.D. Duke 1968, age 41, is currently director of the Physics Division at LASL. He is not well known for his research and is not well known in Washington. He has the reputation, however, of being a very capable scientist with a flair for administration in part the reason for his relative obscurity within the science community is related to the nature of his classified work at Los Alamos. Although he comes from 'outside of the traditional ranks,' Keyworth's credentials appear to be more than adequate for the present requirements of the post of science advisor.—*PMB*

New Publications

Remote Sensing in Geology

B. S. Siegal and A. R. Gillespie, John Wiley, New York, xii + 702 pp., 1980, $42.50.

Reviewed by Mark Settle

Geologists have traditionally employed a wide variety of 'remote sensing' techniques to obtain insight into the structure and lithology of crustal materials. Seismic methods, for example, are used to infer the configuration and physical properties of subsurface rock units through the analysis of acoustic wave measurements performed at or near the earth's surface. In recent years, however, the term remote sensing has come to be used in a more restrictive sense, to refer to the measurement of electromagnetic radiation that is reflected or emitted from the earth's surface. In this context, geological remote sensing is a relatively new and rapidly evolving field within the earth and planetary sciences. It is highly interdisciplinary in nature, involving individuals with backgrounds in various aspects of geology, geophysics, geochemistry, mathematics, engineering, and computer science.

Remote Sensing in Geology is one of a number of books that describe the basic principles, current methodology, and past accomplishments of geological remote sensing methods. The stated purpose of the book is to provide students in geology with 'a complete introduction to most of the aspects of remote sensing.' It takes a certain amount of bravery to devote one's time to the preparation of an introductory text on an emerging, multidisciplinary, scientific field, but several factors suggest that Siegal and Gillespie will be rewarded for their effort. *Remote Sensing in Geology* has been released at a time when interest in remote sensing methods is increasing, as evidenced by the inclusion of remote sensing courses in college curricula and expanding utilization of space-acquired data in geological studies. Furthermore, the collection of new and different types of data by currently planned sensor systems is likely to accelerate interest in geological remote sensing in the future.

Remote Sensing in Geology can be subdivided into two halves. The first half describes how remote sensing measurements are made and how the data collected by these measurement techniques is reduced and analyzed. The second half of the book describes past applications of remote sensing methods to geologic mapping, mineral exploration, glacial and geomorphic studies, engineering and environmental geology, and planetary exploration. The book was written by a group of highly qualified researchers with recognized expertise in different aspects of geological remote sensing. Each chapter within the book was prepared by an individual member of this group, in his or her area of specialization. This results in a somewhat uneven style of presentation. However, the chapters are organized in a logical fashion and the editors have diligently avoided any duplication of effort.

The book provides a comprehensive introduction to past research results and current measurement capabilities in geological remote sensing. However, it would be a mistake to view *Remote Sensing in Geology* as a self-contained text. In my opinion, the book would need to be supplemented with more specialized literature and more detailed case study examples of successful remote sensing projects to be used as an instructional text. The book lends itself to this type of use, in that each chapter contains an excellent bibliography of key references, and all of the images employed as illustrations are carefully documented.

Individuals involved in geological remote sensing may quibble with the emphasis or style of presentation in certain sections. I personally felt that thermal infrared and microwave imaging techniques should have received greater emphasis in the second half of the book. In addition, it seemed to me that several chapters in the second half devoted too much space to describing the geological characteristics of the earth's crust at the expense of describing how remote sensing techniques can be used to study these characteristics. It is quite conceivable, however, that someone with a background in engineering or computer science would have a very different reaction.

In an overall sense, *Remote Sensing in Geology* attains its stated goal. The editors and the authors are to be commended for preparing a comprehensive summarization of the current state-of-the-art within a rapidly maturing, interdisciplinary field. *Remote Sensing in Geology* is potentially useful for students, instructors, and researchers, and its audience is likely to grow throughout the 1980's.

Mark Settle is with the Office of Space and Terrestrial Applications, NASA Headquarters, Washington, D.C.

The Science and Wonders of the Atmosphere

S. D. Gedzelman, John Wiley, New York, xiv + 535 pp., 1980, $19.95.

Reviewed by Raymond C. Staley

Stanley Gedzelman and his associates at John Wiley have given us an attractive and scientifically satisfying introductory college survey text. The book is planned for students with no science or mathematics beyond that ordinarily required in junior high or middle school. Indeed, most of the text can be studied and understood satisfactorily by any ninth grade student who enjoys reading and who has some aptitude for science and mathematics. Every physical law introduced is explained, often with an accompanying historical background, and a worked-out numerical application is given. The book contains 48 numerical examples, along with about 75 similar problems to be solved by the reader. (These 75 problems are part of nearly 500 end-of-chapter questions spaced throughout the text. Hints to answers are given in a section at the back of the book.) Some college students using this text have complained that it is, at times, condescending, especially in these examples. Gedzelman has reason for introducing and emphasizing these examples and problems. He wants to overcome the fear so many students have of word problems and equations: '. . . I have found that despite the tearing of hair and gnashing of teeth among my nonscience students the first time they see me put an equation on the blackboard each semester, they inevitably perform (well) . . . and a few even revel in their new-found mathematical talent.' One of Gedzelman's first numerical examples shows how Eratosthenes estimated the earth's circumference, using the summer solstice position of the sun at Aswan and Alexandria in the noon sky. Gedzelman gives the historical picture and problem in three brief paragraphs; he then states the problem in sentence form, next in equation form, and finally gives a numerical solution in metric units. Most examples include a careful word statement, a statement in algebraic equation form, and a numerical solution. (In my opinion some examples could be improved by using only SI units and by more emphasis on dimensions and units. In examples 5.1 and 5.5 the millibar is mixed with SI units and unexplained dimensional conversion factors to give answers in SI units.)

Gedzelman strives to catch and hold the reader's interest with three introductory chapters on the wonders of the atmosphere such as optical phenomena and extreme and disastrous weather events. In his introduction he also uses the reader's assumed familiarity with TV weather broadcasts to initiate and support the study of surface weather charts.

The five chapters which follow contain very brief but probably adequate glances at the solar system and the atomic and molecular nature of the earth's entire atmosphere and introduce the concepts of pressure, energy, temperature and heat transfer. Chapters 8–14 move the reader rapidly through the heat budget of the earth, the hydrologic cycle and hydrometeors, including sections on thermodynamic diagrams, atmospheric stability and cloud physics, as well as descriptive sections on air pollution and agricultural meteorology. Chapters 15 and 16 explain how the earth's wind systems are driven and present climatological pictures of the wind distribution. Chapters 17 and 18 bring us back to the surface weather chart and introduce the 500 mbar chart. Chapters 19 and 20 look at local winds and storms, and Chapter 21 takes a brief glance at present-day forecasting methods. The remaining four chapters give a picture of the world's climates now and in the past, concluding with a brief look at the way weather and climate have affected land forms, human health and history, and (not least of all) the arts: literature, drama, and painting.

The text is obviously too long for the usual one semester or one quarter course. Gedzelman regards many sections as alternate and optional material. The instructor building a course on this textbook must select from it very carefully to construct the sort of one-term course desired. The book will serve best the instructor who has strong training in meteorology. (Contrary to Gedzelman's remark on p. 8, the text will not produce a reader who is '. . . almost a professional meteorologist by the end of the book.')

The text is attractive with large, clear neatly printed double column pages. Useful tables and well-drawn figures abound. The publisher has used two colors in printing the text material, black and maroon. This is fine for most people, but a total loss for the color-blind reader. It would have helped in many figures if red lines had been dashed and if red shading could have been stippled. In the numbered bibliography, advanced textbooks and sources are numbered in red. My color-blind colleague tells me he cannot distinguish the red from the black numbers (asterisks would have done the job).

I have not taught using this text, but I have discussed it with lecturers and teaching assistants who have used it. Lecturers are enthusiastic, while teacher assistants have mixed feelings, mainly because of what they see as the aforementioned condescending attitude of the author. I do not object to this, but I am annoyed in a few places by what I call 'cutesie' illustrations (especially the misleading Figure 1.5 which shows cartoon pedestrians feeling the earth's Coriolis force). Another fault (common to most such texts) is the omission of Alaska, Hawaii, Canada, Puerto Rico, and adjacent oceans from most weather charts and most synoptic discussion.

The text contains an excellent 12-page glossary of over 600 items. The 11-page index is detailed and very helpful.

An instructor using this text will probably want to add more numerical problems for homework drill. The text problems and questions should be read and checked before assignment. Gedzelman sometimes plays games with the problems (for example, problem 10.10 intentionally asks an impossible question). The instructor should be aware of this before writing a note to the author or publisher.

If you are a meteorologist teaching a course where this might be the text, I urge you to request an examination copy from the publisher and give it serious consideration. I think you would enjoy using it.

Raymond C. Staley is Visiting Scholar, Department of Atmospheric Sciences, University of Washington, Seattle, Washington.

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POSITIONS AVAILABLE

Research Faculty Positions in Physical Oceanography. The Department of Oceanography at the University of Washington invites applications for research faculty positions in physical oceanography. Applicants should have a strong experimental or theoretical background and must have a capability of developing a funded research program and teaching graduate level courses. Level of appointment will depend on the qualifications of the candidate.

The Department has a broad spectrum of on-going activities, operates three research vessels, and has strong interactions with other units in the University, such as the Applied Physics Laboratory and the Department of Atmospheric Sciences.

Applications with supporting data and four letters of reference should be sent to: Chairperson, Recruitment Committee, Department of Oceanography WB-10, University of Washington, Seattle, WA 98195.

The University of Washington is an equal opportunity/affirmative action employer.

Research Position/Space Plasma Physics. Applications are invited for two possible research positions in the Department of Space Physics and Astronomy, Rice University.

One position involves work on a computer code for simulating the large-scale dynamics of the earth's ionosphere and magnetosphere, including computer simulation of specific events and comparison with ground and satellite data. Preference will be given to applicants having experience with space or laboratory plasma physics, and with large computations.

The second possible position involves analysis of data from Atmospheric Explorer and Dynamics Explorer spacecraft. Preference will be given to applicants having experience with space plasmas and with reduction of spacecraft data.

Title and salary for either position will be arranged, depending on experience. Please send resume and bibliography to R. A. Wolf or P. H. Reiff, Department of Space Physics and Astronomy, Rice University, Houston, TX 77001.

Rice University is an equal opportunity/affirmative action employer.

Meteorologist/Remote Sensing. Immediate opening for candidate with a PhD in Meteorology with post graduate research experience and interest in Remote Sensing.

Send resumes to: Melba Houston, Technical Recruiter, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, Maryland 20840.

An equal opportunity employer.

Research Assistant. A position is immediately available for a person in the International Ground Water Modeling Center of the Holcomb Research Institute, Butler University, Indianapolis, Indiana. Successful applicant will have a hydrological background, preferably in ground water, and should have a Master of Science degree. The person must be acquainted with modeling principles, have a working knowledge of FORTRAN IV, experience in computer use, and should be able to communicate and work with a variety of individuals and institutions, both from the United States and abroad.

Primary duties of the position are to assist the Principal Investigator in updating the data base of the Model Annotation Retrieval System (MARS), and in screening and testing acquired models. Incumbent will also be responsible for entering and retrieving model annotations in, or from, the MARS data base. This person will insure the technical content of the ground water modeling newsletter and write technical reports in cooperation with other project members. Other technical and organizational duties will be assigned by the Principal Investigator.

Persons interested in applying for the position should send resumes by July 7, 1981 to:
Darrell R. Fishel
Business Manager
Holcomb Research Institute
Butler University
Indianapolis, Indiana 46208

Butler University is an equal employment opportunity employer.

Research Associate. Position available July 1 for new Ph.D scientist in climatology-glaciology. Work involves research in ice-climate synoptic interactions based on analysis of satellite imagery and digital data (Nimbus and DMSP systems) of climatological and cryospheric parameters using multivariate statistical techniques. Research is performed in a cooperative university-government laboratory employing scientists engaged in interdisciplinary work related to the environment. Position requires experience in analysis and display of remote sensing data and in data processing, demonstrated ability to write scientific reports, background of glaciological-meteorological field research in polar areas; experience in interpretation of snow cover, sea ice, and cloud conditions from visible, IR, and ESMR microwave imagery and digital data; experience with multivariate statistical analysis techniques, especially as applied to meteorological or related data; experience in FORTRAN programming in a CDC Kronos or NOS operating environment; and research experience in synoptic climatology and ice-climate interactions.

Salary approximately $17,000 per year. Applicants should contact the Colorado Job Service, 1701 33rd Street, Boulder, Colorado 80303, telephone (303) 443-6300, and refer to job order number 2217769, for referral to the employer, which is an equal opportunity affirmative action employer.

Temporary Staff Positions in Isotope and Trace Element Geochemistry. The research program of the new Geochemistry Division at the Max-Planck-Institute for Chemistry in Mainz is oriented toward the geochemical structure and development of the earth's mantle. Our facilities include a new Varian MAT 261 automated solid source mass spectrometer (in addition to older instruments) for isotopic analysis of Nd, Sr, and Pb.

Available at the institute are also: electron microprobe, ion microprobe, INAA, XRF, spark source MS, and pistion-cylinder apparatus. Applications are invited for geochemists with experience in isotope geology and petrologists with experimental experience in trace element partitioning. Appointments are normally made for two years, but a one year extension is possible.

Applicabons should be sent to A W. Hofmann, Direktor Abteilung Geochemie, Max-Planck-Institute fuer Chemie, Postfach 3060, 6500 Mainz, F.R Germany.

Professor of Space Physics. The Institute of Geophysics and Planetary Physics of UCLA invites applications for an academic ladder faculty position in the field of space physics. The appointment is expected to be made at the level of professor. Applicants should have well established records in research in the area of fields and particles in space, and will be expected to conduct vigorous research programs in space plasma physics. Responses should include a resume of education, professional experience, and published research. Send replies to L. Knopoff, Associate Director, Institute of Geophysics & Planetary Physics, UCLA, Los Angeles, CA 90024

UCLA is an equal opportunity/affirmative action employer

Physical Oceanographer/ Geophysical Fluid Dynamicist

Areté Associates, a growing research firm, located in Southern California, engaged in theoretical and empirical physical oceanography, is offering permanent, full-time positions. Candidates require Ph.D. (or equivalent experience) in physical oceanography or geophysical fluid dynamics. Salaries are competitive and negotiable, based on qualifications. Areté offers a fringe benefit package of superior quality. Qualified candidates should send résumé, salary history, and list of professional references to:

Personnel Administrator
Areté Associates
P.O. Box 350
Encino, CA 91316

An equal opportunity employer M-F.

Research Coordinator PHYSICAL OCEANOGRAPHY
Skidaway Institute
Savannah, GA.

Skidaway Institute of Oceanography is seeking person with an oceanographic, meteorological or engineering background to join a research team investigating physical oceanographic processes on the continental shelf. This person must operate and maintain a remote oceanographic data acquisition system and must have experience with digital equipment and the processing of data originating from such equipment. He or she will be responsible for checking and calibrating sensors on a scheduled basis, for data editing and for data analysis

Applicants should have an M.S. degree in a related field or have the equivalent in training and experience. Knowledge of time series analysis procedures and techniques, computer programming, and technical report writing are necessary skills. Independent research and publication of results will be encouraged.

Starting Salary: $16,600-$20,000 depending upon previous experience and qualifications. Send résumé including three references to: Dr. Jack Blanton, Skidaway Institute of Oceanography, P.O. Box 13687, Savannah, GA 31406. Phone (912) 356-2457/2453.

SKIO is an affirmative action/equal opportunity employer.

Sedimentologist or Sedimentary Petrologist/University of California, Santa Barbara. *(Correction)* Applications are invited for a tenure track appointment in soft rock geology to be filled in 1981-82. Rank dependent on qualifications and experience but preference will be given to the assistant professor level. Applicant should normally have a Ph D. and strong field-orientation and quantitative background The candidate will be expected to develop a strong research program in sedimentation. The candidate will also be expected to teach at both undergraduate and graduate levels and interact with students and faculty of the department, particularly in the general areas of diagenesis, volcanic processes, paleomagnetics, as well as field geology. Additional duties may include teaching physical geology and summer field geology.

Please send resume, other documentation of abilities, and four letters of recommendation by September 30, 1981 to Dr. Arthur G. Sylvester, Chairman, Department of Geological Sciences, University of California, Santa Barbara, CA 93106. Telephone (805) 961-3156.

The University of California is an affirmative action/equal opportunity employer.

Geophysical Oceanography Postdoctoral Research Associate. The Department of Oceanography, University of Washington, is seeking qualified candidates for a Post-doctoral Research Associate position, available January 1982, to carry out research on interpretation of marine refraction data. A strong background in elastic wave propagation, inverse theory (including linear programming), and modern refraction data processing will be most helpful, as will an acquaintance with petrologic theories of oceanic lithospheric composition. Appointments are for one year, possibly extended for a second year. Send curriculum vitae and a list of four references to: Chairperson, Faculty Recruitment Committee, Department of Oceanography WB-10, University of Washington, Seattle, WA 98195.

The University of Washington is an equal opportunity/affirmative action employer.

Scientist. Immediate opening for Scientist with experience in Lidar Analysis Techniques and Optics. Familiarity with Laser and Optics instrumentation a plus. Candidate must possess a PhD in Atmospheric Science/Optics/Physics.

Send resumes to: Melba Houston, Technical Recruiter, Systems and Applied Sciences Corporation, 6811 Kenilworth Avenue, Riverdale, Maryland 20840.

An equal opportunity employer.

Postdoctoral Position in Geochemistry/ Cosmochemistry, University of Arizona. Applications are invited for a postdoctoral research associateship in the Lunar and Planetary Laboratory at the University of Arizona. The associate will collaborate with Dr. William V. Boynton in ongoing investigations of the refractory inclusions in carbonaceous chondrites. The selected applicant will have major responsibilities to conduct mineralogical investigations to supplement existing neutron activation analysis studies. Experience with an electron microprobe is essential; experience with neutron activation is desirable. Facilities include a fully automated SEM/microprobe, numerous gamma-ray detectors including a Compton-suppression spectrometer, several computers and a TRIGA reactor.

Applications, accompanied by a resume, statement of research interests, and complete bibliography, should be sent to Dr. William V. Boynton, Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721. Letters of recommendation, directed as above, should be requested from at least three persons who are well acquainted with the applicant's accomplishments and potential. To receive full consideration, application materials should be received by August 31, 1981.

The University of Arizona is an equal opportunity/ affirmative action employer.

Faculty Position/Geophysics. The Department of Geological Sciences at the University of Texas at El Paso has an opening in geophysics which can be filled at either the assistant or associate professor level. The emphasis will be on obtaining a quality individual regardless of specialty. However, candidates who would complement existing programs in geothermics, crustal studies, seismotectonics, and regional geophysics/tectonics will be given preference. The successful candidate must hold a doctoral degree and will be expected to maintain a high level of research activity and to be active in the geophysics graduate program which involves 15-20 students (roughly ½ doctoral candidates). The geophysics program is well equipped and enjoys good support from the university administration. The deadline for applications is July 15, 1981 with the position to be filled prior to September 1, 1982 Applications and three letters of reference should be sent to:

Dr. Robert F. Roy
Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968.

The University of Texas at El Paso is an equal opportunity/affirmative action employer.

Electron Microprobe Technical Specialist University of Colorado. The department of Geological Science, University of Colorado, Boulder, seeks a person who will assume responsibility for the department's electron microprobe laboratory. Duties will include day-to-day operation of our MAC 400 microprobe equipped with a KEVEX EDS system, instruction of new operators, maintenance of the microprobe as well as other X-ray equipment within the Department, microprobe software and hardware development, and participation in research projects involving silicate, sulfide and oxide mineralogy. The job requires either a degree in electronic or electrical engineering, or two years of technical experience utilizing electronic instrumentation associated with an electron column instrument. An individual with an M.S. degree in Geology and microprobe experience will be considered highly desirable. Salary ranges from $20,000-$25,000 depending on experience. Please send, by August 15, letter of application and resume to Bruce Badger, Personnel Department, University of Colorado, 1511 University Avenue, Boulder, CO 80309.

The University of Colorado is an equal opportunity/affirmative action employer.

Research Seismologist/Solid Earth Geophysics. ENSCO, Inc. in Springfield, Virginia is seeking a Program Manager/Research Seismologist to support an expanding program in solid earth geophysics. Research areas will include: seismic network data processing associated with the detection, identification and location of natural and man-made seismic sources; earthquake characterization and source mechanism studies; explosion source characterization; and empirical studies using near field and far field seismic data. Experience in theoretical and observational seismology at regional and teleseismic distances, is highly desirable. Experience in digital time series analysis is desirable. Ph.D. in seismology is highly desirable, however, M.S. level with experience in earthquake and explosion seismology will be considered. Salary and benefits are extremely competitive. Resumes along with salary requirements should be submitted to the Personnel Department at the address below, Attention Code SAS, ENSCO, Inc., 5408-A Port Royal Road, Springfield, VA 22151.

Equal employment opportunity/AAP

Marine Sciences Institute/Research Assistant II. Salary $12,500 p.a. To conduct analyses of trace elements in seawater and other matrices by ultra-clean techniques; assist in the development of new analytic techniques; participate in oceanographic field work; assist in preparation of technical reports; coordinate laboratory and field programs. M.S. degree in appropriate area of analytical chemistry, geology or oceanography, or B.S. with 2 years experience. Experience with atomic absorption/emission spectrophotometry, gas chromatography, ultra-clean solvent extraction for trace metals, simple computer programming; experience working at sea. Reply to D. Wasienchuk at the University of Connecticut, Marine Sciences Institute, Groton, CT 06340.

Equal opportunity employer h/v.

Geophysicist/Tectonophysicist. The Department of Geology and Geophysics at the University of Wyoming has a tenure track opening at the Associate Professor level for a geophysicist/tectonophysicist. An interest in velocity measurements and other physical properties of rocks is essential. Additional interest in crustal structure and plate tectonics is desirable. Applicant should be able to relate studies of physical properties to field relationships. Ph.D. required.

Applications will be accepted through July 15, 1981. Applicants should send a vita, including names of three references, to:

Professor R. S. Houston
Department of Geology/Geophysics
University of Wyoming
Laramie, Wyoming 82071

The University of Wyoming is an equal opportunity/affirmative action employer.

Marine Chemistry. Applications are invited for either of two tenure track faculty positions that carry teaching and research responsibilities. The level of appointment and salary will be commensurate with achievement and experience. One position is oriented toward the area of application of organic chemistry to natural systems. The other position is oriented toward research utilizing inorganic or radiochemistry in understanding atmospheric or oceanic processes. Ability to develop independent research programs will be a primary consideration.

Send resume, references and summary of research interests to: Search Committee, Division of Marine and Atmospheric Chemistry, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, Florida 33149.

The University of Miami is an equal opportunity/ affirmative action employer.

Scripps Institution of Oceanography

is soliciting applications for a postdoctoral fellowship in any aspect of marine geology, marine geochemistry, or marine geophysics for one year beginning fall 1981. Applicants should submit names of three references, bio-bibliographies, reprints, and a statement of research interest. Preference will be given to recent Ph.D.s. Salary will be approximately $19,500 depending upon experience and publications.

No moving expenses can be paid. Submit applications to Chairman, Geological Research Division, A-020, Scripps Institution of Oceanography, La Jolla, CA 92093, no later than August 1, 1981.

The University of California, San Diego is an equal opportunity/affirmative action employer.

Faculty Position Space Physics & Astronomy

The Department of Space Physics and Astronomy of Rice University expects to fill a regular faculty position beginning August 1982. Academic rank and tenure status will be determined on the basis of experience.

Preference will be given to experimentalists who are Principal Investigators for experiments on present or planned spacecraft missions. However, consideration will be given to other qualified candidates in the general areas of space physics, astrophysics, and atmospheric science.

Applicants should send resumes and bibliographies to

Professor A. J. Dessler
Chairman
Department of Space Physics and Astronomy
Rice University, Houston, TX 77001.

Rice University is an equal opportunity/affirmative action employer. No candidate is presently under consideration in advance of this notice.

Hydrogeochemist. Hydrogeochemist for Water Resources Center to conduct research studies including those related to geochemical and hydrologic analysis of Great Basin ground and surface water systems, and salting and hydrothermal geochemical problems. Duties include use of geochemical and hydrodynamic computer models and their adaptations to meet project needs; and design and management of field geochemical research projects. Requires MS or BS with five years experience in geochemistry, hydrology, or geology; experience in interactive computing with aqueous geochemical models; experience in design and implementation of field geochemical research projects including various field measurements and sample collection; knowledge of physical flow dynamics as applied to solute transport; demonstrated ability to work with others on a variety of research problems; knowledge of various laboratory procedures used in aqueous and mineral analysis. The successful candidate will be offered a six-month contract based on an annual salary of $18,000-$21,000, depending upon qualifications and experience. Send resume and letter of application, postmarked by July 15, 1981 to Personnel Department, Desert Research Institute, University of Nevada System, P.O. Box 60220, Reno, Nevada 89506.

An affirmative action/equal opportunity employer.

SERVICES

Scripps Remote Sensing Tutorials.

1A. *Overview of the Remote Sensing Facility*—This one-day seminar describes the data bases, sources and processing capabilities available at Scripps Institution of Oceanography, Remote Sensing Facility. A morning lecture will introduce past, current and future space platforms available for observation of the Oceans. A brief discussion of where and how to access this information will conclude the first part of the class.

The afternoon will include a demonstration of processing and displaying imagery obtained from TIROS-N, NOAA-6 and NIMBUS-7.

Classes will be held at the Helen Reitt Room SIO Library on Monday, April 20, 1981 and Monday, July 27, 1981, at 8:30 am. A nonrefundable fee of $50.00 must be submitted with the application. Enrollment limit—12.

2A. *Users Introduction to the Scripps Remote Sensing Facility*—This four-day workshop is intended exclusively for individuals who will be using the facility at Scripps. Two morning lectures will describe in detail the hardware, software and personnel resources available to oceanographers. Existing data bases, their characteristics, location, mode and cost of access will be covered. Basics of image processing will be introduced along with in-depth look at the Interactive Digital Image Manipulation System used at the SRSF.

The two lectures will be followed by afternoon lab sessions which consist of hands-on exercises to familiarize users with the hardware/software at the facility. The third morning will be devoted to train users in realtime spacecraft tracking and data recording and acquisition.

The remainder of the 3rd day and the entire 4th day will be used to work with users on a one-to-one basis. Attendees are encouraged to bring their own digital tapes with data of interest to them, which can be used during this last portion of the workshop.

Classes will be held in the Helen Reitt Room SIO Library starting on Tuesday, April 21, 1981 and Tuesday, July 27, 1981 at 8:30 am. A fee of $335.00 must be submitted with each application. Enrollment limit—6.

For more information regarding applications, fees, etc., please contact University of California at San Diego, SRSF/SIO, Mail Code A-030, La Jolla, California 92093 or (714) 452-2292.

ANNOUNCEMENTS

28th Annual Report on Research under Sponsorship of The Petroleum Research Fund. Containing 898 technical progress reports, bibliography, and information on the ACS-PRF program of grants-in-aid for "... advanced scientific education and fundamental research in the petroleum field ..." is available gratis upon request to: The Petroleum Research Fund, American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. 20036.

Meetings

Call for Papers

Ocean Sciences: AGU/ASLO Joint Meeting

A joint meeting of the American Geophysical Union's Oceanography Section and the American Society of Limnology and Oceanography will be held February 16–19, 1982, in San Antonio, Texas. The El Tropicano Hotel is headquarters for the meeting, with additional housing available at the St. Anthony and the Gunter hotels.

OCEAN SCIENCES AGU/ASLO Joint Meeting February 16-19, 1982 San Antonio, Texas

Abstracts must be received at the AGU office by 5 P.M. on November 10 to be on time. Late abstracts (1) may be summarily rejected by program chairman, (2) may not be published in advance of the meeting, and (3) if accepted, will be charged a $25 late fee in addition to the regular publication charge.

General Regulations

Abstracts may be rejected without consideration of their content if they are not received by the deadline or are not in the proper format.

There is a publication charge of $40 ($30 if prepaid) for each abstract. The publication charge is $20 if the first author is a student. Both invited and contributed papers are subject to the publication charge. Prepayment of the publication charge can save you money. Send a check for $30 with your abstract ($15 for students).

The abstract must be received at AGU by November 10 to avoid an additional $25 charge.

Authors will be notified by mail in early January of the status of their papers.

Abstracts

Use standard AGU format and send original and two copies of abstracts to AGU Ocean Sciences Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, January 19, 1982. Copies will be sent to all ASLO members.

The abstract page is divided into two parts; the abstract itself and the submittal information. Follow the instructions for both carefully. Abstracts that exceed the noted size will be trimmed to conform to the proper dimensions.

Submission of an abstract for an AGU meeting is presumed to carry with it permission for AGU to reproduce the abstract in all editions of *Eos* and in the programs and reports relating to the meeting; it is also presumed to permit the free copying of those papers. Although *Eos* is a copyrighted journal, authors are not requested to transfer copyright; copyright, where it exists, will be reserved by the authors.

Program Committee

Convenors: Worth D. Nowlin, Jr., Department of Oceanography, Texas A&M University, College Station, TX 77843, (713) 845-2947; Richard W. Eppley, Institute of Marine Resources, A-018, S.I.O., University of California at San Diego, La Jolla, CA 92093; (714) 452-2338 (office), (714) 452-3194 (secretary).

Sample Abstract

TECHNIQUE FOR THE PREPARATION OF ABSTRACTS

F. R. S. T. Author (School of Oceanography Hydro University, Watertown, Mass. 02172)
S. C. N. D. Author (USGS, Woods Hole, Mass. 02543)

Follow this example in typing the abstract. The printing plates will be prepared by photographing the abstracts exactly as they are received, except that abstracts exceeding the maximum length (20 cm) or width (10.4 cm) will be cut to conform.

Use a good typewriter with a ribbon in good condition. A carbon ribbon gives the best results. Please use type of about this size. There will be a reduction of about 50% for the printed abstract volume.

Follow these guidelines:

(1) Type title in all capital letters.
(2) Leave one line blank after title.
(3) Type name of first author, affiliation, and address.
(4) Type names of second and following authors, if any, leaving no blank lines between authors.
(5) Underscore the name of author who will present paper.
(6) Leave one blank after author block.
(7) Hand-lettered symbols or Greek letters are acceptable.
(8) Use SI units.

NOTE: There are no special forms distributed for typing abstracts. If necessary this block (10.4 x 20 cm) may be traced on typing paper in nonreproducible blue pencil or may be traced in dark lines on a backing sheet. Be sure, however, to include all information.

(10.4 cm) (20 cm)

Submittal Information

1. Meeting name—Ocean Sciences 1982
2. Corresponding address.—Give complete address and phone number of author to whom all correspondence should be sent. Abbreviate as much as possible.
3. Kind of presentation—Indicate your preference with one of the following letters: O for oral, P for poster. The chairman may assign your paper to either of these types of presentation in order to fit his program plan.
4. Type title of special session (if any) to which submittal is made.
5. Give the percent of material previously presented or published and where.
6. Billing information:
   a. Complete billing address if other than the corresponding address (item 2 above).
   b. If purchase order is to be issued, indicate number. (Please have issuing department list name of first author and title of paper on P.O.)
   c. Student rate applicable.
7. Indicate whether paper is C (contributed) or I (invited). If invited, list name of inviter.

Abstract Deadline: November 10, 1981
Mail original and two copies to:
Ocean Sciences Meeting
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

AGU Midwest Meeting

September 17–18
Minneapolis, Minnesota

Abstract Deadline: July 1
Convenor: V. Rama Murthy

Papers and posters originating in or pertaining to the region are solicited for the following special sessions:

Mantle structure and dynamics. Contact Geoffrey Davies or Clem Chase.

Rock water interactions: Hydrothermal processes and metallogenesis. Contact William Seyfried.

Precambrian crustal evolution of the North American continent. Contact Paul Weiblen.

Geomagnetism and paleomagnetism. Contact Subir Banerjee.

Hydrology of the mid-continental U.S. Contact H. Quinn Illangasekare or E. C. Alexander, Jr.

Abstracts.

Use standard AGU format (see page 20 of January 13 *Eos*) and send original and two copies of abstracts to AGU Midwest Meeting, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Abstracts will be published in *Eos*, with a substantive meeting report after the meeting. There will be no abstract charge.

Members: Charles D. Hollister, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, (617) 548-1400; Peter Jumars, Ocean Science and Technology Division, Office of Naval Research, 800 N. Quincy Street, Arlington, VA 22217, (202) 696-4590; Claire Schelski, Great Lakes Research Division, University of Michigan, Ann Arbor, MI 48109, (313) 764-2422; and Karl Turekian, Geology Department, Yale University, Box 2161, Yale Station, New Haven, CT 06520, (203) 436-0377.

Special Sessions

Ocean Climate and Biological Productivity Connections
Overview of Large Oceanographic Projects
Biology and Physics of Gulf Stream Rings
Relations Between Biology and Circulation in the Gulf of Mexico
Geological Effects of Ocean Circulation
Anthropogenic Inputs to the Ocean: Diverse Points of View
Processes and Resources of the North Pacific Shelves
Small Lake Limnology
Marine and Freshwater Bioturbation
Ocean-River Interaction: Sedimentation and Chemistry
Particle Fluxes in the Water Column and Benthic Boundary Layer
Relations between Mesoscale Physical and Biological Processes
Coastal Processes
Biological and Physical Measurement Techniques
Microscale Processes and Effects on Biota
Physics and Biology of Ice Edges
Physical, Chemical and Biological Processes in Large Lakes

ANTON L. HALES SYMPOSIUM

The Geosciences Program of The University of Texas at Dallas will sponsor a Symposium entitled

"SOME RECENT ADVANCES IN GEOPHYSICS"

on October 5–6, 1981, in honor of Dr. Anton L. Hales on his 70th birthday.

The Symposium will consist of two days of invited talks by internationally known speakers from academia and industry on recent developments in geophysics with an emphasis on seismology. Topics will include recent COCORP results, modelling reflection seismograms, heterogeneous earth structure, attenuation of seismic waves, and global tectonics.

For additional details and registration information, contact Richard M. Mitterer or Ronald W. Ward, Programs in Geosciences, The University of Texas at Dallas, P.O. Box 688, Richardson, Texas 75080. Telephone: 214-690-2401.

Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

June 29–July 2 22nd United States Symposium on Rock Mechanics, Cambridge, Mass. Sponsor, Massachusetts Institute of Technology. (Barbara Dullea, Coordinator, Center for Advanced Engineering Study Seminars, MIT, Cambridge, MA 02139.)

June 29–July 3 Conference Workshop on Heterogeneous Catalysis—Its Importance to Atmospheric Chemistry, Albany, N.Y. Sponsors, NSF, NASA. (V. A. Mohnen, Atmospheric Sciences Research Center, State Univ of New York, Albany, NY 12222.

June 29–July 11 Seminar on Fluid-Dynamical Problems in Astrophysics and Geophysics, Chicago, Ill. Sponsors, American Mathematical Society, Society for Industrial and Applied Mathematics. (Meeting Arrangements Department, American Mathematical Society, Post Office Box 6248, Providence, R.I.)

July 6–11 Geocongress '81-South African Geodynamics Project and 3rd International Platinum Symposium, Pretoria, South Africa Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat S. 217, CSIR, P.O. Box 395, Pretoria 0001 Republic of South Africa.)

July 8–10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsor, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 15–17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Buchanan, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21–23 **Chapman Conference on Spatial Variability in Hydrologic Modeling,** Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

July 21–30 21st General Assembly of IASPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27–30 **Eighth International Symposium on Urban Hydrology, Hydraulics, and Sediment Control,** Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 206B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug 3–15 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug 4–7 International Conference on Energy Education, Providence, R.I. (Donald Kirwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9–15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, ICCL, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 9–18 International Congress of Surveyors, F.I.G., Montreux, Switzerland Sponsor, Federation Internationale Des Geometres (American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug 10–14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10–14 Water Forum '81; Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22041.)

Aug. 10–19 20th General Assembly of the International Union of Radio Science, Washington, D.C. (R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418.)

Aug. 17–28 Third Scientific Assembly of IAMAP with Extraordinary General Assembly, Hamburg, Federal Republic of Germany. (S. Rutlenburg, NCAR, P.O. Box 3000, Boulder, CO 80307.)

Aug. 17–18 Open Symposium on Mathematical Models of Radio Propagation, Washington, D.C. Sponsor, URSI. (J. R. Wait, Bldg. 20, Electrical Engineering Department, Univ. of Arizona, Tucson, AZ 85721.)

Aug. 17–22 **Ninth International Symposium on Earth Tides,** New York, N.Y. Sponsors, IAG, IUGG, Columbia Univ. (J. T. Kuo, 828 S.W. Mudd, Columbia Univ., New York, NY 10027.)

Aug. 18–21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Haigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5061.)

Aug. 20–21 Second International Symposium on Computer-Aided Seismic Analysis and Discrimination, North Dartmouth, Mass. Sponsors, Electrical Engineering Department, Southeastern Massachusetts University, IEEE Computer Society, IEEE Acoustics, Speech and Signal Processing Society. (C. H. Chen, Electrical Engineering Department, Southeastern Massachusetts University, North Dartmouth, MA 02747.)

Aug. 24–26 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodaetisk Institut. (C. C. Tscherning, International Symposium Management of Geodetic Data, Geodaetisk Institut, Gamlehave Alle 22, Charlottenlund DK-2920 Denmark.)

Aug. 24–29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (C.-E. Lund, Chairman Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 556, 22 Uppsala, Sweden.)

Aug. 25–27 The Royal Institution of Chartered Surveyors Centenary Celebration, London, England. (Representative Radlinski, American Congress on Surveying and Mapping, 210 Little Falls Street, Falls Church, VA 22046.)

Aug. 26–Sept. 9 Arc Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan, IAVCEI. (Daisuke Shimozuru, IAVCEI Symposium on Arc Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31–Sept 2 Third International Colloquium on Mars, Pasadena, Calif. Sponsors, NASA, Lunar and Planetary Institute, Division of Planetary Sciences of the AAS. (Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109.)

Aug. 31–Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 Munchen 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairman of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c o LNEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7–12 Third International Symposium on Antarctic Glaciology, Columbus, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society. (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 8–12 American Society of Photogrammetry-American Congress on Surveying and Mapping Fall Convention, San Francisco, Calif. (L. W. Aggers, USGS, 345 Middlefield Road, Mail Stop 31, Menlo Park, CA 94025.)

Sept. 13–17 National Water Well Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 16–18 **Oceans '81,** Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering, AGU. (R. Nagle, Publicity Manager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept. 17–18 **Midwest Meeting,** Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept. 17–18 **Pacific Northwest Regional Meeting,** Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 98920.)

Sept. 20–22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept. 28–Oct. 10 NATO Advanced Study Institute on Chemistry of the Unpolluted and Polluted Troposphere, Corfu, Greece. (W. Jaeschke, Center of Environmental Protection, University of Frankfurt, Robert-Mayer-Str. 11, 6000 Frankfurt/Main, FRG.)

Oct. 6–8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. El-Shaarawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 7–9 John Muir Geophysical Society's Fourth Nonannual Meeting, Lake Arrowhead, Calif. (M. McNutt, USGS, Menlo Park, CA 94025.)

Oct. 11–14 Coastal Society's Seventh Annual Conference, Galveston, Tex. (N. West, Coastal Society Conference, Department of Geography and Marine Affairs, Univ. of Rhode Island, Kingston, RI 02881.)

Oct. 11–15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 446, La Habra, CA 90631.)

Oct. 13–15 Fifth Geopressured-Geothermal Energy Conference, Baton Rouge, La. Sponsors, Louisiana Geological Survey, Department of Natural Resources; Energy Programs Office, Louisiana State University; U.S. Department of Energy. (Ann Bachman, Conference Coordinator, Energy Programs Office, 105 Hill Memorial, Louisiana State Univ., Baton Rouge, LA 70803.)

Oct. 13–16 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hapke, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14–16 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 633 Sixth Ave., S.W., Calgary, Alberta, Canada T2P 2Y5.)

Oct. 19–22 Earth Impact Conference, Snowbird, Utah. Sponsors, Lunar and Planetary Institute, National Academy of Sciences. (Earth Impact Conference, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Oct. 22–24 Fourth Conference on the Physics of the Jovian and Saturnian Magnetospheres, Laurel, Md. Sponsor, NASA. (S. M. Krimigis, Applied Physics Laboratory, Johns Hopkins Univ., Laurel, MD 20810.)

Oct. 26–30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shorelines Commission of the International Union for Quaternary Research, Scientific Committee of the World Confederation of Underwater Activities. (Patricia M. Masters, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

November 1–5 Sixth Biennial International Estuarine Research Conference, Gleneden Beach, Oreg. Sponsor, Estuarine Research Federation. (Jay F. Watson, Treasurer, USFWS Suite 1982, 500 N.E. Multnomah Street, Portland, OR 92232.)

Nov. 2–6 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Ames Research Center, Moffett Field, CA 94035.)

Nov. 9–11 Special Conference on the Mechanical Behavior of Salt, University Park, Pa. Sponsor, Rock Mechanics Laboratory, Department of Mineral Engineering, Pennsylvania State University. (H. Reginald Hardy, Jr., Rock Mechanics Laboratory, Room 117, Mineral Sciences Building, Pennsylvania State University, University Park, PA 16802.)

Nov. 9–20 Second Symposium on Geodesy in Africa, Nairobi, Kenya. Sponsors, IAG, IUGG Local Committee of Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography. (R. Omandi, Survey of Kenya, P.O. Box 30046, Nairobi, Kenya.)

Nov. 30–Dec. 11 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM, Research Division, Box 218, Yorktown Heights, NY 10598; or G. S. Watson, Bernoulli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08544.)

Dec. 3–5 **Topical Conference on the Processes of Planetary Rifting,** San Francisco, Calif. Sponsor, Lunar and Planetary Institute. (Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Dec. 7–11 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 18–19 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluva, Istituto di Petrografia, Via Gramsci 9, 43100 Parma, Italy.)

1982

Jan. 11–14 Symposium on the Understanding of Hydrologic Processes at the Basin Scale, Caracas, Venezuela. Sponsors, Universidad Simón Bolívar, IAHS. (Ignacio Rodriguez-Iturbe, Universidad Simón Bolívar, Apartado Postal 80.659, Caracas 1081, Venezuela.)

Feb. 8–12 **Third International Geodetic Symposium on Satellite Doppler Positioning,** Las Cruces, N. Mex. Sponsors, Defense Mapping Agency, National Ocean Survey, AGU. (Richard Peat, Defense Mapping Agency, Hydrographic/Topographic Center, 6500 Brooks Lane, N.W., Washington, DC 20315.)

Feb. 18–19 **Ocean Sciences: AGU/ASLO (American Society of Limnology and Oceanography) Joint Meeting,** San Antonio, Tex. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Mar. 22–26 International Symposium on Hydrothermal Reactions, Yokohama, Japan. Sponsor, Tokyo Institute of Technology. (Shigeyuki Sōmiya, Research Laboratory of Engineering Materials, Tokyo Institute of Technology, Nagatsuta, Midori, Yokohama, 227 Japan.)

Mar. 24–27 Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, Hayward, Calif. Sponsors, USGS, East Bay Council on Surveying and Mapping, Calif. Div. of Mines and Geol., Woodward-Clyde Consultants, Calif. St. Univ. at Hayward. (Sue Hirschfield, Dept. of Geological Sciences, California State University, Hayward, CA 94542.)

Apr. 11–16 Penrose Conference on Antarctica, Shenandoah National Park, Va. Sponsor, GSA. (Ian W. D. Dalziell, Lamont-Doherty Geological Observatory, Columbia University, Palisades, NY 10964.)

April 19–21 Cordilleran Section, Geological Society of America and Seismological Society of America Annual Meeting, Anaheim, Calif. (Neil Maloney, Earth Science Department, California State Univ., Fullerton, CA 92634.)

April 27–29 **Chapman Conference on Rainfall Rates,** Urbana, Ill. (Meetings, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009.)

May 3–7 **14th International Liège Colloquium on Ocean Hydrodynamics,** Liège, Belgium. Sponsors IAPSO, Unesco Marine Sciences Division, EGS, Intergovernmental Oceanographic, AGU. (Jacques C. J. Nihoul, University of Liège, Mecánique des Fluides Géophysiques-Environment, B6- Sart Tilman, B-4000 Liège, Belgium.)

May 7–20 General Meeting of IAG, Tokyo, Japan. (I. Nakagawa, Geophysical Institute, Kyoto University, Sakyo-ku, Kyoto 606 Japan.)

May 10–12 Fourth International Conference on Planning and Management of Water Resources for Industrial, Agricultural, and Urban Use, Marseilles, France. Sponsors, Commission Européenne Mediterranéenne de Planificaotn des Eaux (C.E.M.P.E.), Société des Eaux de Marseille (S.E.M.), the Bureau de Recherches Géologiques et Minières (B.R.G.M.), Centre de Formation Internationale à la Gestion des Ressources en Eau (CEFIGRE), UNESCO, Commission des Communautés Européennes, Association des Hydrogéologues (AIH). (Secretariat de la Conference, Société des Eaux de Marseille, 25 rue Edouard Delanglade—13008 Marseille, France.)

May 24–June 4 International Solar-Terrestrial Physics Symposium, Ottawa, Ontario, Canada. (Professor Liu, University of Illinois, Urbana, IL 61801.)

May 24–June 4 24th Plenary Meeting of COSPAR Ottawa, Ontario, Canada. (Dean Kastel, Space Sciences Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington DC 20418.)

May 25–28 **Symposium on the Composition of Nonurban Troposphere,** Williamsburg, VA. Sponsors, AMS, NASA, AGU. (Jack Fishman, Mail Stop 401-B, NASA Langley Research Center, Hampton, VA 23665.)

May 31–June 4 **AGU Spring Meeting,** Philadelphia, Pa. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

June 13–17 International Symposium on

AAPG American Association of Petroleum Geologists
AMS American Meteorological Society
ASCE American Society of Chemical Engineers
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHS International Association for Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association of Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science

FUTURE AGU MEETINGS

Fall Meetings
December 7–11, 1981, San Francisco
December 6–10, 1982, San Francisco
December 5–9, 1983, San Francisco

Spring Meetings
May 31–June 4, 1982, Philadelphia

Hydrometeorology, Denver, Colo. Sponsor, American Water Resources Association. (A. I. Johnson, Woodward-Clyde Consultants, 2909 West 7th Ave., Denver, CO 80204.)

June 15–18 **International Conference on Rainwater Cistern Systems,** Honolulu, Hawaii. Sponsors, University of Hawaii's Water Resources Research Center, AGU. (Yu-Si Fok, General Conference Chairman, Water Resources Research Center, Univ. of Hawaii, 2540 Dole Street, Honolulu, HI 96822.)

June 27–July 2 Fifth International Conference on Geochronology, Cosmochronology, and Isotope Geology. Nikko National Park, Japan. (K. Shibata, Geological Survey of Japan, Higashi 1-1-3, Yatabe, Ibaraki 305 Japan.)

July 19–30 Scientific Meeting of IAHS with Extraordinary General Assembly, Exeter, United Kingdom. (John C. Rodda, Department of the Environment, Water Data Unit, Reading Bridge House, Reading RG1 8PS United Kingdom.)

Aug. 2–13 Joint Oceanographic Assembly, Halifax, Nova Scotia, Canada. Sponsor, Scientific Committee on Oceanic Research. (Leo O'Quinn, National Steering Committee for JOA, c/o Canadian Committee on Oceanography, 240 Sparks St., Ottawa, Ontario K1A 0E6 Canada.)

Aug. 2–6 Second International Symposium/Workshop on Solar-Terrestrial Influences on Weather and Climate, Boulder, Colo. Sponsor, Lockheed Palo Alto Research Laboratory. (Billy M. McCormac, Lockheed Palo Alto Research Laboratory, Dept. 52-13/B202, 3251 Hanover Street, Palo Alto, CA 94304.)

Aug. 15–21 Fourth International Symposium on Antarctic Earth Sciences, Ingle Farm, South Australia, Australia. Sponsors, Australian Academy of Science, Australian Academy of Technological Sciences, International Union of Geological Sciences, Scientific Committee on Antarctic Research, Geological Society of Australia, Inc., Univ. of Adelaide. (J. B. Jago, South Australian Institute of Technology, P.O. Box 1, Ingle Farm, South Australia, Australia 5098.)

Aug. 15–22 International Meeting on Generation of Major Basalt Types, Reykjavik, Iceland. Sponsors, IAVCEI, IAGC. (Basalt Meeting, c/o G. E. Sigvaldason, Nordic Volcanological Institute, 101 Reykjavik, Iceland.)

Aug. 15–22 IAVCEI and IAGC Joint Meeting, Reykjavik, Iceland. (G. E. Sigvaldason, Nordic Volcanological Institute, Univ. of Iceland, Geosciences Building, 101 Reykjavik, Iceland.)

Aug. 22–28 11th International Congress on Sedimentology, Hamilton, Ontario, Canada. Sponsor, IAS. (IAS Congress 1982, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada.)

Aug. 22–28 **Third Circum-Pacific Energy and Mineral Resources Conference,** Honolulu, Hawaii. Sponsor, IUGS. (AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101.)

Aug. 23–27 Second Symposium on Applied Glaciology, Hanover, N.H. Sponsor, International Glaciology Society. (Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom.)

Aug. 24–27 Ninth Annual Meeting of the European Geophysical Society, Leeds, United Kingdom. (J. C. Briden, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, England.)

Sept. Third International Kimberlite Conference, Clermont-Ferrand, France. (Francoise Boudier, Université de Nantes, Laboratoire de Tectonophysique, 2 Rue de la Houssiniere, 44072 Nantes, France.)

May or Sept. Scientific Meeting of IAPSO, Halifax, Canada. (E. C. LaFond, LaFond Oceanic Consultants, P.O. Box 7325, San Diego, CA 92017.)

Dec. 6–10 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

1983

July 18–23 Fourth International Conference on Permafrost, Fairbanks, Alaska. Sponsors, National Academy of Sciences, State of Alaska. (L. De Goes, Polar Research Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

Aug. 15–26 18th General Assembly of IUGG, Hamburg, Federal Republic of Germany. (P. Melchior, Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180 Bruxelles, Belgium.)

Aug. 27 Symposium Commemorating the 100th Anniversary of the Mount Krakatau Eruption, Jakarta, Indonesia. Sponsor, Indonesian Institute of Sciences. (Didin Sastrapradja, Deputy Chairman for Natural Sciences, LIPI JL. Teuku Chik Ditiro 43, Jakarta, Indonesia.)

Sept. 12–14 National Water Well Association 35th Annual Convention and Exposition, St. Louis, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Dec. 5–9 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

AGU

Nominations for New VGP Award Sought

At the 1981 Spring Meeting in Baltimore, the VGP Executive Committee voted to establish a VGP Award. The guidelines for the award are as follows:

I. Basis for the Award

The award is to be given for a single outstanding contribution to volcanology, geochemistry, or petrology made during the preceding 5 years. The contribution may be: (1) a single outstanding paper published in any journal; (2) a series of papers which, taken together, constitute an outstanding contribution; and (3) any other contribution that the Selection Committee considers worthy. The award will be accompanied by a suitable certificate, with the recipient's name and year of award, signed by the president of the VGP Section.

II. Number of Awards

The award may be given to as many as five or as few as zero individuals during any calendar year. Multiple awards may be either shared awards or separate awards, as appropriate.

III. Nominations

Nominations for the award may be made by any member of AGU. They must be accompanied by a written statement of the basis for nomination. Copies of the contribution(s) for which the person is nominated should accompany the nomination statement if appropriate. Nominations may be submitted to the chairman of the Selection Committee or to any officer of the VGP Section for transmittal to the Committee.

IV. Eligibility

Any member of the scientific community is eligible for the award, but no individual may receive the award more than once. The Committee is charged with seeking out scientists whose work has not been recognized by the receipt of other awards, but this charge is not a restriction on the award.

V. Selection Committee

The Selection Committee shall consist of five AGU members affiliated with the VGP Section. Each member shall have a tenure of 3 years. Terms will overlap to provide continuity to the Committee. One or two members—as appropriate—shall be appointed each year by the president of the VGP Section after consultation with the other VGP officers. The VGP President shall determine the tenures of the members of the initial Selection Committee.

VI. Committee Chairman

The chairman of the Selection Committee will be selected by the president of the VGP Section from among the second- or third-year members of the Committee.

VII. Committee Recommendations

The Selection Committee shall make an annual recommendation to the Executive Committee of the VGP Section as to who should receive the award. The recommendation shall include the nominating statement(s) of qualifications and a draft, or drafts, of suitable citations. The Executive Committee of the VGP Section has veto power and may refuse or return any recommendation to the Selection Committee for further consideration. The Executive Committee shall reach their decisions by majority vote of those in attendance or communication. In case of tie votes the VGP Section President will have the final authority. The Selection Committee shall also submit the names and qualifications of all nominees considered for the award to the Executive Committee, who will consider the nominees for possible nomination for AGU Fellowship.

VIII. Award Schedule

May—Announcement in *Eos* soliciting nominations from AGU membership. July—Selection Committee members and AGU membership make nominations to the chairman August—Committee comes to a consensus. September—Committee recommends the annual recipients of the award to the VGP Executive Committee. October—Executive Committee takes action on recommendations. Secretary arranges for announcement in *Eos* and for certificates. December—Award made at Western Meeting of AGU. Executive Committee may decide to have award made at the Fall Eastern Meeting if circumstances warrant delay in presentation. April—President of section selects new members for Committee and designates new chairman in accordance with paragraphs V and VI above.

Nominations for the first VGP Award, which will be presented at the 1981 Fall Meeting in San Francisco, are now being sought. AGU members should send nominations and appropriate supporting material to the VGP President (Wallace Broecker), President-Elect (Joseph V. Smith), or Secretary (G. Brent Dalrymple) for transmittal to the Selection Committee.

GAP

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Particles and Fields—Magnetosphere

5715 Electric fields
PAIRED ELECTROSTATIC SHOCKS
M. Temerin Space Sciences Laboratory, University of California, Berkeley, California 94720 M. K. Roth and R. L. Mozer
The detection of 31 paired electrostatic shocks from a portion of the ISS-1 satellite data set has shown that in 30 cases the electric field in the equatorial half of the paired shock pointed toward the electric field in the poleward half of the poleward shock pointed equatorward. At the same time the electron, ion, and wave data indicated the presence of an electron loss cone and a region of ion heating in the region between the paired shocks. This parallel electric field was at an altitude below that of the satellite and pointed out of the ionosphere so as to accelerate ions upward. A comparison of the potential across the accelerated ions with the energy of the corresponding ion beam-electrostatic shock and the energy of the corresponding ion beam-associated with paired electrostatic shocks closely agrees with the energy of maximum flux given reasonable agreement. Theoretical particle distributions and several ion and electron-acoustic shocks, several accelerated). Geophys. Res. Lett., Paper 1L0669

5736 Magnetic Tail
ESTIMATES OF THE NORTH-SOUTH ELECTRIC FIELD COMPONENT IN THE MAGNETOTAIL ION LAYERING BOUNDARY LAYER
N. Candidi and S. Orsini (IPS/CNR CP 27, 00044 Frascati (Roma) Italy)
The measurements of E_y ion drift velocity in the magnetotail boundary layer are used to infer the E_z component of the local electric field. It is shown that E_z is generally a substantial component of the field and that it reverses its sign from the dawn to the dusk side of the northern magnetotail between $X_{GSE} = 15$ R_E and $X_{GSE} = 25$ R_E (Electric field, magnetic field, magnetotail boundary layer).
Geophys. Res. Lett., Paper 1L0567

5755 Plasma Instabilities
STABILIZATION OF THE ELECTROSTATIC KELVIN-HELMHOLTZ INSTABILITY IN RING CURRENT PLASMAS
J. Huba, Naval Research Laboratory, Washington, D.C.
A fully self-consistent theory of the electrostatic Kelvin-Helmholtz instability in finite beta plasma is presented. The instability is driven by a parallel velocity flow which is sheared transverse to the magnetic field. The important features of our analysis are: Vlasov theory is used so that finite Larmor radius effects and wave-particle resonances are properly treated; the complete coupling of electrostatic and electromagnetic oscillations is considered (i.e., both resonant and nonresonant) are treated self-consistently. The primary result is that the electrostatic Kelvin-Helmholtz instability is unstable in high β plasmas. The actual value of β for stabilization depends upon the parameters. The stabilization is mainly attributed to resonant and nonresonant ∇B effects. These results are applied to several space plasmas (i.e., polar cusp, cometary tails, magnetopause) and estimates of the nonlinear diffusion coefficient associated with this instability are presented.
J. Geophys. Res., Blue, Paper 1A0939

5755 Plasma Instabilities
TRANSIENT MONOLINEAR PITCH ANGLE SCATTERING OF ENERGETIC ELECTRONS BY COHERENT VLF WAVE PACKETS IN THE MAGNETOSPHERE
T. F. Bell (Radioscience Laboratory, Stanford University, Stanford, Ca., U.S.A.) U. S. Inan
With the aid of adiabatic theory, a study is made of the transient nonlinear pitch angle scattering experienced by energetic electrons under the influence of coherent VLF wave packets in the magnetosphere. Finite wave packets of both fixed and variable frequency are considered, as are wide ranges of b-ball, wave frequency and wave amplitude. Our results indicate that large wave path angle changes can be induced in the portion of the energetic particle population which undergoes a nonlinear cyclotron resonance interaction with the wave packet. Two classes of nonlinearly interacting particles are identified, the nonlinearly resonant particles trapped in the wave and the nonlinearly resonant nontrapped particles. It is shown that the mean pitch angle change of these two classes of particles are of opposite sign, but that the mean pitch angle change of the ensemble can still be significant. In the case of fixed-frequency wave packets on oblique shells near $L = 4$, trapped particles typically experience pitch angle changes of 5° or more for remote wave amplitudes (~10 mV). In the case of variable-frequency wave packets, similar changes can be produced with much lower wave amplitudes (~2 mV). We conclude that the utilization of transient nonlinear pitch angle scattering effects offers interesting options for energetic particle control during ground- or space-based VLF wave injection experiments.
J. Geophys. Res., Blue, Paper 1A0422

5760 Plasma Motion, Convection, or Circulation
PROPAGATING SUBSTORM INJECTION FRONTS
T.E. Moore, (Space Science Center, University of New Hampshire, Durham, N.H. 03824) R.L. Arnoldy, J. Feynman, and D.A. Hardy
The geosynchronous ATS-6 Environmental Measurements Experiment was operated during fifteen evening passes when the SCATHA spacecraft was within 3 Rg and both spacecrafts were very near the geomagnetic equator. Numerous, well defined substorm injections were recorded at both spacecrafts with varying local time and radial separations. Accurate delay timing was possible since these events exhibit abrupt and recurring dispersionless (to within 10 sec) plasma flux changes which replace cool pre-existing plasma with hot quasi-Maxwellian distributions. The hot plasma propagates Earthward in close association with an equally abrupt magnetic field increase at velocities in the range of 10-100 km/sec. On this basis we identify the agent of injection as the inbound electric field of the Earthward propagating compression wave observed by Russell and McPherron, and we refer to the propagating particle structure as the injection front. These dramatic synchronous orbit electron signatures are produced mainly by a boundary motion rather than by local acceleration of plasma. However, we find some evidence that the plasma sheet electrons are weakly "spread" by the passage of each compression wave, the energy spreading mainly in the high energy tail of the distribution. The spectral change we observe argues convincingly that the boundary in question is a precipitation-free boundary layer and that the near-Earth plasma sheet is significantly degraded in average energy by the addition of ionospheric plasma, especially secondary electrons emitted by the ionosphere due to precipitating energetic electrons. The presence of significant E_y is required that a change of mapping occur between the equatorial plane and the ionosphere; the sense being such as to map the forward moving injection front to a relatively fixed latitude in the ionosphere. The lack of equatorward directed surface expansion during substorms is thus fully consistent with Earthward plasma injection.
R. Hoegy, NASA, Paper 1A0447

5760 Plasma motion, convective, or circulation
ON THE VELOCITY DISTRIBUTION OF ION JETS DURING SUBSTORM RECOVERY
J. Birn (Ruhr-Universität Bochum, 4630 Bochum, W. Germany), T.G. Forbes, E.W. Hones, Jr., S.J. Bame (University of California, Los Alamos National Laboratory, Los Alamos, NM 87545, USA) and G. Paschmann (Max-Planck-Institut für Physik

and Astrophysik, Institut fur Extraterrestrische Physik, Garching, W. Germany)
The velocity distribution of eastward streaming ions that are observed during substorm recovery by satellites at ~15 to 35 R_E in the magnetotail is compared quantitatively with two different theoretical models, the "adiabatic deformation" of an initially flowing Maxwellian moving into higher magnetic field strength, (A), and the field aligned electrostatic acceleration of an initially non-flowing isotropic Maxwellian including "adiabatic deformation" effects, (B). It is assumed that the ions are protons or more generally consist of only one species. Both models can explain the [illegible] distribution function. Model (A), however, gives a somewhat better overall quantitative agreement with the observed distributions, leading us to conclude that field aligned electrostatic acceleration may not play the fundamental role in the energizing of the [illegible] suggested earlier (Frank et al., 1976; De Coster and Frank, 1979). The two models imply different plasma conditions in the tailward source region. Model (A) requires a source in the far tail with plasma of kT ≈ 1 keV and density less than that at the observing satellite. Model (B) requires a source, probably closer to the satellite position, with plasma of kT ≈ 2-5 keV and density greater than that at the observing satellite. The conditions at the source region implied by Model (A) are consistent with the plasma's having originated in the tail lobes and having been accelerated by a reconnection process in the far tail.
J. Geophys. Res., Blue, Paper 1A0552

5770 Short-period (less than 1 day) variations of magnetic field
A STUDY OF PI2 PULSATIONS AT CANADIAN OBSERVATORIES
[illegible] (Earth Physics Branch, Energy, Mines and Resources, Ottawa, K1A 0Y3, Canada)
The analysis of the Pi2 pulsations for the period Dec 15, 1970 to May 14, 1971 from Ottawa, [illegible], Baker Lake and Resolute Bay observatories gives the following: 1) Pi2 pulsations occur most frequently near midnight at Ottawa, [illegible] and Baker Lake and near 1571 MLT or [illegible] for the [illegible] MLT peak at Baker Lake [illegible] during [illegible] at Baker Lake and Resolute Bay [illegible] during magnetically [illegible] at earlier hours during [illegible] 2) The [illegible] of Pi2 is found to be larger before [illegible] at Ottawa and [illegible] and at midnight at Baker Lake. 3) The period of Pi2 is [illegible] in the morning and evening in the [illegible] at Ottawa and [illegible]. Also Ottawa [illegible] that Pi2 [illegible] of variation. 4) Both the [illegible] of Pi2 are found to [illegible] with increasing magnetic activity to a certain level of Kp [illegible] the [illegible] evidence of a 27-day [illegible] tendency in the period of Pi2 is found. A [illegible] influence on the occurrence of Pi2 is also noted and this effect deserves further attention.
J. Geophys. Res., Blue, Paper 1A0492

5770 Short-period (less than 1 day) variations of magnetic field
THE DEPENDENCE OF UPSTREAM WAVE PERIODS ON THE INTERPLANETARY MAGNETIC FIELD STRENGTH
C.T. Russell (Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024 USA) and M.M. Hoppe
It has long been known that the periods of Pc 3, 4 pulsations on the ground correlate with the magnitude of the interplanetary magnetic field strength. This fact has been used to argue for an upstream source for these pulsations. Particularly attractive candidates for the source of pulsations in this frequency range are the upstream waves of similar frequencies which are [illegible] with particles reflected from the bow shock. However, the dependence of the period of these waves on the strength of the interplanetary magnetic field has never been [illegible]. This paper performs such a check and confirms that the upstream waves have the proper functional relationship. (Upstream waves, Pc 3-4, magnetic pulsations)
Geophys. Res. Lett., Paper 1L0724

5770 Short-period (less than 1 day) variations of magnetic field
[illegible] 6. RELATIONSHIP TO [illegible] SOLAR WIND PARAMETERS
[illegible] and Bell Laboratories, Murray Hill, N.J. [illegible]
Geomagnetic energy densities, computed at [illegible] intervals in three frequency bands from magnetometer data at Pittsburg, N.H. (L = 3.5) for 28 days during July and August 1975, are correlated with upstream solar wind parameters obtained from instruments on the IMP-J spacecraft. The diurnal ground magnetic energy variations generally show higher power levels for the lower frequency fluctuations. [illegible] the power levels may appear at different local times on individual days. Dayside and nightside ground hourly magnetic energies are generally found to correlate best with the solar wind kinetic energy flux density, $F_k = \frac{1}{2} m n V^3$ from amongst the various upstream interplanetary quantities examined. The highest linear correlation coefficients found between power vs. F_k and power vs. V_{sw} are generally obtained during local afternoon hours, with a sharp reduction in correlation occurring at local noon. We conclude that different interplanetary wave mechanisms contribute to the dayside ground power in different frequency bands. Improved correlations are expected for nightside power levels with geomagnetic tail quantities rather than with upstream solar wind quantities.
J. Geophys. Res., Blue, Paper 1A0730

5775 Trapped Particles
[illegible] ENERGETIC [illegible] WITH NUCLEAR CHARGE Z ≥ 9 IN THE [illegible] MAGNETOSPHERE
Walther N. Spjeldvik (Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, Colorado [illegible]) and Theodore A. Fritz (Space Environment Laboratory, NOAA, Boulder, Colorado [illegible]).
Ions heavier than protons, such as helium ions and CNO ions, are known to exhibit substantially enhanced trapped fluxes at MeV energies in the interior of the earth's radiation belts associated with some, but not all, magnetic storms. In this report we extend the Explorer 45 heavy ion data analysis to ions heavier than fluorine, i.e., to ions with nuclear charge Z ≥ 9 during and following a major magnetic storm on August 4, 1972. Our heavy ion detector telescope does not permit a precise identification of these ions; but if they are magnesium ions (say), then an equatorially mirroring peak trapped flux of ~0.02 ions/(cm²-sec-ster-keV) is derived on L-shells just below L=3 at energies 33.9 – 51.2 MeV per ion (533-2133 keV per nucleon). Other possible ion contributions include silicon and iron. The fluxes of these ions are found to decay on time scales typically several tens of days. This is substantially faster than that of helium ions and somewhat faster than that of oxygen ions in the lower MeV range. We infer that the pitch angle distributions of the Z ≥ 9 ions were quite anisotropic over a range of L-shells with the exponent n in the relation $j(\alpha) = j_0 \sin^n \alpha$ having a value of at least 10; this value is arrived at from two independent techniques.
J. Geophys. Res., Blue, Paper 1A0776

5775 Trapped particles
ENERGETIC OXYGEN AND SULFUR IN THE JOVIAN MAGNETOSPHERE
N. Gehrels, E.C. Stone (California Institute of Technology, Pasadena, California 91125), and J.H. Trainor
This paper reports measurements made by the Cosmic Ray Subsystem onboard Voyagers 1 and 2 in the Jovian magnetosphere. Energy spectra of oxygen ions in the energy range 1 to 20 MeV/nuc between 5 and 20 R_J are presented and used to calculate phase space densities. There is a steep positive radial gradient in the phase space density of the energetic oxygen ions in this region, indicating an inward diffusive flow. Solutions of the diffusive equation assuming a diffusion coefficient, D, and loss lifetime, τ, of the form $D = D_0 L^n$ and $\tau = \tau_0 L^m$ where D_0, τ_0, n, and m are constants, and L is the McIlwain parameter, are fit to the radial phase space density profile of oxygen ions with magnetic moments of 690 MeV/nuc-G. The best fits are found to have n ≈ -6 and 3 < n < 6. Based on the diffusion coefficient upper limit obtained from these fits, the upper limit on the rate at which oxygen ions with ≥ 400 MeV/nuc-G diffuse inward across 10 R_J is 5×10^{21} ions s^{-1}. The observations suggest that oxygen and sulfur ions in the Io plasma torus diffuse radially outward, are nonadiabatically accelerated in some region outside 17 R_J, and then diffuse inward and outward from the acceleration region.
J. Geophys. Res., Blue, Paper 1A0946

5780 Wave propagation
WAVE-PARTICLE INTERACTIONS NEAR Ω_{He^+} OBSERVED ON GEOS-1 AND 2: 1. PROPAGATION OF ION CYCLOTRON WAVES IN He^+-RICH PLASMA
D.T. Young (Physikalisches Institut, University of Bern, CH-3012 Bern, Switzerland), S. Perraut, A. Roux, C. de Villedary, R. Gendrin, A. Korth, G. Kremser, and D. Jones
The GEOS-1 and 2 spacecraft contain a set of particle and wave detectors which allow for a very comprehensive study of wave-particle interactions occurring within the equatorial region of the magnetosphere. This paper is devoted to interactions involving protons in the energy range 20 keV to 300 keV and ELF waves with frequencies below the proton gyrofrequency. It is shown that most of the ion cyclotron waves (ICW's) detected in this frequency range have spectra whose characteristic frequencies are organized in the vicinity of the He^+ gyrofrequency. Simultaneous measurements of the ion composition in the thermal energy range (< 110 eV) show these waves to be closely associated with the abundance of cold He^+ as well as the anisotropy of ions above 20 keV. The general characteristics of these He^+-[illegible] ELF events are presented in case studies of four events. The interpretation of this phenomenon is given in the present paper in terms of the propagation of ICW's in a He^+-rich plasma. It is shown that the shape of the cold plasma dispersion curve (for both parallel and [illegible] propagation) can adequately explain the main characteristics of the observed waves (frequency spectra, polarization) as well as the differences between [illegible]. The generation conditions of ion cyclotron waves in such a multicomponent plasma, as well as their quasi-linear effects on both the cold He^+ ions and the hot protons, are discussed in a companion paper.
J. Geophys. Res., Blue, Paper 1A0947

5785 Whistlers
[illegible] FINDING FOR LOW-LATITUDE WHISTLERS AND THEIR PROPAGATION MECHANISM
T. [illegible] (Research Institute of Atmospherics, Nagoya University, Toyokawa, Aichi, 442, Japan) [illegible] and A. Iwai
In order to study the propagation mechanism of low-latitude whistlers, their ionospheric exit points have been determined by a triangulation of the goniometer-polarimeter systems at the two stations of Yamaoka(geomag.coord. 20°24'N,197°53'E;L=1.22) and Kagoshima(22°06'N,197°51'E;L=1.25), being supplemented by the routine observation at Sakushima(21°03'N,203°13'E;L=1.28). Detailed analyses are made for 23 January,1978 when the whistler activity is most enhanced during one month's measurement. The differences in temporal variations of the occurrence rate at the three stations and the temporal variation of the single-valued dispersion enables us to subdivide the daytime whistlers into three characteristic time intervals and the nighttime ones into two intervals. The characteristics during the whole intervals are found to be satisfactorily accounted for in terms of ducted propagation. The azimuth measurements have indicated that there is present a discontinuity in the characteristics between each two intervals,being indicative of the different duct group for different time intervals,in other words, of the identity and persistency of ducts for each period. Then we obtain the "apparent life time" of ducts of 1-2 hours. During the last interval for the daytime whistlers,a few ducts are found to be aligned on a certain latitude,which have shown a temporal movement,or have increased first and followed by a decrease. The simultaneous presence of a few ducts at the same latitude is also seen at night.(Whistlers,goniometer,ducts,magnetosphere).
J. Geophys. Res., Blue, Paper 1A0538

Physical Properties of Rocks

6110 Elasticity, fracture and flow
THE GLASS TRANSITION IN BASALT
M. P. Ryan (Geochemistry-Mineralogy Program, Dept. of Geosciences, The Pennsylvania State University, University Park, PA 16802) and C. G. Sammis
The glass transition has been experimentally detected in basalt as (1) an increase in the aggregate linear thermal expansion coefficient, α_L; (2) an abrupt change in the temperature dependence of Young's modulus, dE/dT; and (3) a change in stress relaxation behavior that effectively separates the $T > T_G$ and $T < T_G$ creep regimes. Transition temperatures determined by the respective experimental methods are: (1) 730 ± 15°C, by expansion dilatometry; (2) 725 ± 10°C, by acoustic spectroscopy, and (3) 725 ± 25°C, by stress relaxation. For olivine tholeiite from Kilauea Iki lava lake, Hawaii, thermal expansivity rises through the glass transition interval attaining $\alpha_v = 33.0 \times 10^{-6}$ °C^{-1} at 850°C. For olivine tholeiites with moderate glass contents, the temperature dependence of the Young's modulus changes on either side of the inferred T_G of 725°C, and dE/dT = -0.071 kbar °C^{-1} for $T < T_G$, while dE/dT = -0.21 kbar °C^{-1} for $T > T_G$. Collectively, the mechanical results suggest that for Hawaiian olivine tholeiite at 1 atm. pressure, the principal material responses are: (1) elastic (T ≤ 600°C); (2) reduced creep (600 < T < 725°C); (3) glass transition (T ≈ 725°C); (4) enhanced creep (725 < T < 980°C); (5) partial melt (T > 980°C). Fracture surface morphologies developed during solidification suggest that the presence of the supercooled melt grain boundary phase may participate in the regulation of the thermal cracking process. Well-preserved fracture surfaces formed by incremental crack growth are found to be covered with striations that correspond to the inferred sequential stopping positions of the advancing fracture front. These striae may be rationalized in terms of experimental analogues that have been produced in viscoelastic polymers by cyclic tension-tension loading. The fracture surface morphology, mechanical data, and the controlled crack growth analogues suggest that thermal fracture in solidifying basalt is an incremental and cyclic process, involving three steps: (1) the accumulation of elastic strain energy in cooling rock at temperatures below that required for stress relaxation due to viscous flow in the intercrystalline liquid phase; (2) fracture at a ΔT determined primarily by the aggregate thermal expansion coefficient, α_v, and Young's modulus, E; (3) the penetration by the advancing crack tip, of the thermal horizon capable of relaxing stress due to the creep of intercrystalline supercooled melt, producing the rough surface texture associated with the termination of a striation. Further crack growth must now await the migration of the solidus. The cycle then repeats.
Striations measured in deep Hawaiian lava lakes have been compared with the crack advance increments expected in the vicinity of the glass transition, based on two tests: (1) thermal gradients measured in Kilauea Iki, combined with the mechanical properties of olivine tholeiite evaluated near T_G, and (2) the crack advance required to match the recorded seismic stopping phases for previous cracks of the dimensions expected for Kilauea Iki. The observed vrs. predicted comparisons are: (1) 31 vrs. 36 cm; and (2) 31 vrs. 30 cm. We envision this incremental crack growth process as contributing to the control on the downward movement of the thermal cracking front--and its associated hydrothermal circulation zone--in the upper portions of solidifying subaerial and submarine ponded basalt. (Glass transition, basalt, incremental fracture.)
J. Geophys. Res., Red, Paper 1B0897

6180 Thermal properties
ACOUSTIC VELOCITIES IN HEATED BLOCK OF GRANITE SUBJECTED TO UNIAXIAL STRESS M.S. King (Engineering Geoscience, University of California, Berkeley, CA) and B.N.P. Paulsson
Acoustic velocities have been measured within a 38 cm cubic block of granite isolated from the surrounding rock. The block was subjected to uniaxial stresses in the range 0-24 Mpa and to heating in the range 14° to 98°C. An increase in temperature from 14° to 72°C in the unstressed block resulted in an increase in velocities in directions parallel and perpendicular to the applied stress. A further increase in temperature to 98°C in the unstressed block resulted in a decrease in velocities. Application of uniaxial stress with the block at a temperature of 98°C resulted first in uniform increases in velocity to an applied stress of 10 MPa and then sharp decreases from 10 to 14 MPa, followed by uniform increases in velocity to a maximum stress of 24 MPa. A reduction in temperature to 16°C resulted in a sharp reduction in velocity, 25 percent less than originally measured at ambient temperature. It is concluded that, at temperatures rising to 72°C, anisotropic thermal expansion of the crystals comprising the granite causes the closure of microcracks present in the unheated rock. Between 72° and 98°C, particularly when stress was applied, irreversible mechanical changes occurred in the block.
Geophys. Res. Lett., Paper 1L0866

6190 Instruments and techniques
FACTORS IN THE DESIGN AND MANUFACTURE OF LARGE HIGH PRESSURE AND HIGH TEMPERATURE TRIAXIAL CELLS
A. Du Bois (Lawrence Berkeley Laboratory, Berkeley, California 94720)
Factors important to the design of vessels for testing the physical and hydraulic properties of rock samples of the order of one meter diameter by three meters long are discussed. The stored energy of water and nitrogen pressurized at 60 MPa and 200 C are shown to be comparable. Some constraints imposed by boring needs, vessel material selection, cell geometry, materials handling, and safety are reviewed. (Triaxial cell, rock testing).
Geophys. Res. Lett., Paper 1L0676

6190 Instruments and Techniques
UNDERGROUND LARGE SCALE TEST FACILITY FOR ROCKS
P. N. Sundaram (Lawrence Berkeley Laboratory, Berkeley, California 94720)
There are certain advantages in locating the facility for testing rock specimens of large dimensions in an underground space. Such an environment can be made to contribute part of the enormous axial load and stiffness requirements needed to get complete stress-strain behavior. The high pressure vessel may also be located below the floor level since the lateral confinement afforded by the rock may help to reduce the thickness of the vessel.
Geophys. Res. Lett., Paper 1L0627

6190 Instruments and techniques
ROCK PROPERTIES FOR WHICH LARGE SCALE TESTS MAY BE NECESSARY
William Hustrulid (Colorado School of Mines, Mining Department, Golden, Colorado 80401. U.S.A.)
The potential application of large scale geomechanical testing results to the following five mining/civil engineering problem areas; roof spans, design of rock support-reinforcement systems, design of rock compression members, development/optimization of fragmentation systems, and design of slopes is discussed. It is concluded that such testing does have an application but to be meaningful it must be accompanied by significant field observation measurement programs.
The type of testing facility required is not universal but depends upon the problem to be examined.
Geophys. Res. Lett., Paper 1L0792

6190 Instruments and techniques
EXPERIENCE WITH IN SITU MEASUREMENT OF ROCK DEFORMABILITY
Z. T. Bieniawski (Department of Mineral Engineering, The Pennsylvania State University, University Park, PA 16802
Although in situ tests have the advantage of involving a large volume or rock tested under the same environmental conditions as are prevailing in the rock mass, such tests are expensive and time consuming. In addition, there are a number of controversial questions pertinent to in situ tests.
This presentation discusses the first-hand experience with three in situ test methods. These are: (1) plate bearing tests, (ii) large and small flat jack tests, and (iii) Goodman jack tests. By identifying the problems associated with in situ testing, useful lessons can be learned for large scale laboratory testing in geomechanics. (Rock mechanics; in-situ testing; deformability).
Geophys. Res. Lett., Paper 1L0773

6199 GENERAL OR MISCELLANEOUS
THE EFFECT OF THERMAL CYCLING ON THE SEISMIC QUALITY FACTOR, Q, OF SOME SEDIMENTARY ROCKS
V.A. Clark and T.W. Spencer (Dept. of Geophysics, Texas A&M University, College Station, TX 77843) B.R. Tittmann (Rockwell International Science Center, Thousand Oaks, CA 91360)
Changes in Q in rocks in response to thermal cycling can result from the removal of physisorbed water, an increase in the crack density and therefore the internal surface area, at temperatures greater than 400°C, the removal of chemisorbed OH groups which are the adsorption sites for physisorbed water, and the dehydration of clays.
When rocks are heated to temperatures of 100-200°C, the change in Q is reversible and is due to the removal of physisorbed water. Sioux quartzite and Berea sandstone were thermally cycled to 675 and 385°C respectively. The Q of both rocks increased when measured over a broad range of relative humidities, but decreased at low humidities (10-25%). Measurements of adsorption isotherms for the Berea sandstone showed no loss of adsorptive capacity of the clays. Although the surface area of thermally cracked rocks increased, the number of sites where adsorbed water molecules contribute to attenuation decreased.
J. Geophys. Res., Red, Paper 1B0781

Planetology

6510 Atmosphere of planets
THE ALTITUDE DISTRIBUTION OF THE VENUS ULTRAVIOLET NIGHTGLOW AND IMPLICATIONS ON VERTICAL TRANSPORT
J.C. Gérard (Institut d'Astrophysique, Université de Liège, 4200-Cointe-Liège - Belgium) A.I.F. Stewart and S.W. Bougher
The altitude distribution of the nitric oxide nightglow has been measured with the ultraviolet spectrometer on board Pioneer Venus. Limb profiles obtained near periapsis with a ~5km vertical resolution have been fitted using a method independent of the spacecraft attitude data. It is found that the altitude of the maximum of the layer is 115±2 km and the topside scale height ≈3km. It is shown that downward transport by diffusion alone is insufficient. If vertical motion is parametrized by eddy diffusion, an eddy diffusion coefficient K ≈$8^{+8}_{-4} \times 10^{12}/M^{1/2}$ cm^2.s^{-1} is deduced from the altitude of the layer.
Geophys. Res. Lett., Paper 1L0563

6510 Atmospheres of Planets
KRYPTON AND XENON IN THE ATMOSPHERE OF VENUS
T. M. Donahue (Department of Atmospheric and Oceanic Science, University of Michigan, Ann Arbor, MI 48109) J. H. Hoffman and R. R. Hodges, Jr.
Probable values of the mixing ratios of krypton and its isotopes on Venus by the Pioneer Venus large probe neutral mass spectrometer are reported. An upper limit to most of the xenon isotope mixing ratios is also set. Based on a ^{36}Ar mixing ratio of 30 ppm the krypton mixing ratio is probably 47 ppb and its upper limit is 69 ppb. The upper limit for Xe is 120 ppb but there is probably considerably less than 40 ppb. Atmospheric krypton and xenon on Venus exceed terrestrial values by factors of 3.5 and no more than 30, much less than the ratios for neon and argon. It appears that the noble gases on Venus have a large solar component compared to Earth and Mars. (Rare gases, atmosphere, Pioneer-Venus, mass spectrometer).
Geophys. Res. Lett., Paper 1L0561

6510 Atmospheres of planets
SUNLIGHT ABSORPTION BY AEROSOLS IN JUPITER'S UPPER ATMOSPHERE
Robert A. West (Laboratory for Atmospheric and Space Physics and Astro-Geophysics Department, University of Colorado, Boulder, Colorado, 80309)
The amount of sunlight deposited in the Jovian upper atmosphere is estimated from reflectivity measurements at 2400 Å by the Voyager 2 Photopolarimeter experiment and at visible and near-IR wavelengths observed by Pioneer 10 and ground-based instruments.
Zero to about one percent of the incident energy is absorbed at altitudes above the 100 mbar level in models with mean values for haze optical depth and single scattering albedo. Several percent of the incident energy could be absorbed, if limiting values are used, and if an additional absorbing layer is incorporated below the high altitude haze in Pioneer models. Maximum absorption occurs at the edge of the polar regions near ±65° latitude. Most of the absorbed energy is derived from visible and near-IR radiation rather than UV radiation. (Jupiter atmosphere, aerosols, absorption).
Geophys. Res. Lett., Paper 1L0724

6510 Atmospheres of Planets
IO: COULD SO_2 CONDENSATION/SUBLIMATION CAUSE THE SOMETIMES REPORTED POST-ECLIPSE BRIGHTENING?
F. P. Fanale* and W. B. Banerdt (Space Science Division, Jet Propulsion Laboratory, California Institute of Technology; *Currently at Hawaii Institute of Geophysics, University of Hawaii) and D. P. Cruikshank
Io's sometimes-reported post-eclipse brightening may be caused by SO_2 frost formation during eclipse and sublimation on emergence. The known properties of SO_2 can be used to explain quantitatively the amplitude of brightening and its duration, and (qualitatively) its variability.
Geophys. Res. Lett., Paper 1L0723

6510 Atmosphere of Planets
FLOW FIELDS WITHIN JUPITER'S GREAT RED SPOT AND WHITE OVAL BC
J.L. Mitchell (Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91103) R.F. Beebe, A.P. Ingersoll, and G.W. Garneau
Using sequences of Voyager 1 high-resolution images of Jupiter's Great Red Spot (GRS) and White Oval BC we map the flow fields within the GRS and Oval BC. We compute relative vorticity within these features as a function of semi-major axis length and position angle in a coordinate system consisting of concentric ellipses of equal eccentricity. Both the velocity and relative vorticity profiles are nearly identical for Oval BC and the outer portion of the GRS. Wind speeds of 110-120 m/sec are observed near the outer edges of both features. Along their minor axes relative vorticity profiles reach a maximum of ~6 × 10^{-5}sec^{-1}. This is several times greater than the ambient 1.5 × 10^{-5}sec^{-1} meridional shear of zonal winds at the latitudes of the GRS and Oval BC. Maximum Rossby numbers of 0.36 are computed for flows within both the GRS and Oval BC. Generally, the Rossby numbers within these features are much lower, indicating strongly geostrophic constraints on the flow. The difference in streamline curvature within the GRS and Oval BC is found to compensate for the difference in planetary vorticity at the respective latitudes of the features. Motions within the central region of the GRS are much slower and more random than around the spot's outer portion.
J. Geophys. Res., Green, Paper 1C0447

6510 Atmospheres of planets
COLORS ON JUPITER
Tobias Owen (Earth and Space Sciences, SUNY, Stony Brook 11794) and Richard J. Terrile.
The colors present in the clouds of Jupiter at the time of the Voyager encounters are described as they appeared in high resolution images. Although many different tints are present in these pictures, some cloud units can be characterized by very discrete colors. We can show that latitude, altitude, and dwell-time are all critical factors in determining which colors appear where, but the identities of the responsible chromophores remain unestablished. Simultaneous ground-based 5µm observations permit the determination of the relative altitudes of these cloud systems. In descending order, we have the white clouds (presumably ammonia cirrus), the light brown or tawny clouds (ammonium hydrosulfide and/or monosulfide(?)), a dark brown cloud belt present only at some latitudes, and the blue-grey "hot spots" of the equatorial region. The top of the Great Red Spot may exceed the altitude of the white clouds on occasion. Despite the turbulence of the Jovian atmosphere, correlations between cloud color and certain latitudes have been maintained for decades, suggesting the importance of the internal energy source and the deep circulation in generating some of the observed chromophores. (Jupiter, colors, atmosphere, clouds).
J. Geophys. Res., Green, Paper 1C0770

6510 Atmospheres of planets
THE VOYAGER 1 EUV SPECTRUM OF THE IO PLASMA TORUS
D.E. Shemansky (Space Sciences Institute, Univ. of Southern Calif., Tucson Laboratories, Tucson, Arizona 85713) G.R. Smith
The Voyager 1 EUV spectrum of the hot Io plasma torus has been analysed using a collisional model. The estimated effective electron temperature of the central dense region of the plasma is 8 × 10^4 K. The torus half width number densities (cm^{-3}) obtained from the model calculation are OII (50), OIII (340), OIV (≤17), SII (44 ± 20), SIII (160), SIV (220), SV (≤11), XIII (≤5). The relative oxygen/sulfur number densities are ΣOn/ΣSn = 0.9. Comparison of the model calculations with other spectroscopic observations that can be clearly identified as originating in the hot plasma torus shows satisfactory agreement. However the EUV observations show strong morphological differences with recent ground based observations of SII emission raising questions concerning excitation mechanisms and radial dependence of the observed characteristics. The ion densities indicated by the EUV data analysis show distinct differences with the in situ Voyager 1 plasma science estimates.
J. Geophys. Res., Blue, Paper 1A0638

6510 Atmospheres of Planets
MODULATION OF VENUS ION COMPOSITION ASSOCIATED WITH SOLAR VARIATIONS
S. J. Bauer (NASA/Goddard Space Flight Center, Greenbelt, Maryland, 20771) and H. A. Taylor
The dayside ion concentrations in the Venus ionosphere obtained by the Pioneer Venus orbiter ion mass spectrometer exhibit a modulation corresponding to the 27-day solar variation. Comparisons were made of the amplitudes of modulation of CO_2^+, C^+, and O_2^+, with the amplitudes of the 27-day variation in the 10.7 cm solar radio flux and the simultaneously measured EUV fluxes at He II (304A) and Lyman β (1026A). Together with a theoretical analysis of the effects of solar variability on the ionosphere and neutral atmosphere of Venus. This analysis leads us to the conclusion that the observed modulation of dayside ion densities is primarily due to the variability in the ionizing EUV radiations and, to a much lesser extent, the result of the variability with solar activity of the neutral atmosphere via the variability in exospheric temperature. In this connection, we also show, theoretically, why the percentage variation of exospheric temperature on Venus (as observed in the ONMS data) for a given variation in F10.7, is only half of the exospheric temperature variation for Earth.
Geophys. Res. Lett., Paper 1L0813

6510 Atmospheres of planets
HOT OXYGEN ATOMS IN THE UPPER ATMOSPHERE OF VENUS
A. F. Nagy (Space Physics Research Laboratory, Department of Atmospheric and Oceanic Science, University of Michigan, Ann Arbor, MI 48109) T. E. Cravens, J-H. Yee and A. I. F. Stewart
The energy distribution of "hot" oxygen atoms in the upper atmosphere of Venus was calculated using two different numerical methods. The two different approaches were based on 1) 2-stream transport and 2) diffusion equation considerations. Dissociative recombination of molecular oxygen ions and charge exchange of atomic oxygen ions with the neutral hydrogen and oxygen gas were the source terms considered; the calculations show that the dissociative recombination term is the dominant one. The altitude distribution of the hot oxygen atoms above the exobase was also calculated and compared with measurements by the Pioneer Venus Orbiter Ultraviolet Spectrometer. The calculated densities show an altitude dependence similar to that obtained by the measurements, but are larger by a factor of about four to five. We find that the concentration of hot oxygen atoms is comparable to or exceeds that of thermal hydrogen atoms throughout much of the dayside exosphere.
Geophys. Res. Lett., Paper 1L0718

6510 Atmospheres of planets
STUDIES OF JUPITER'S LOWER IONOSPHERIC LAYERS
Robert Hsin Chen (Center for Radar Astronomy, Stanford University, Stanford CA 94305)
Theoretical calculations are made of the formation of heavy ions necessary to form the layers of enhanced ionization observed in the lower ionosphere of Jupiter. The results show that if the layers are formed from sodium or sulfur ions of Galilean satellite origin injected into the Jovian atmosphere then, in order to match the Pioneer 10 observations of the L_6 layer, the Na$^+$ flux must be about 3 × 10^4 cm^{-2}s^{-1} and the S$^+$ flux must be about 4 × 10^3 cm^{-2}s^{-1}. From the shape of the ionization layers estimates of ion drift velocities and neutral wind speeds may be made. The vertical ion drift velocities range from a few cm/sec to m/sec while the zonal wind shear ranges from 50 m/sec westward to 200 m/sec eastward over a 70 km altitude range and small (cm/sec) meridional winds are sufficient to form the layers. (Jupiter, ionosphere, layers)
J. Geophys. Res., Blue, Paper 1A0777

6530 Gross properties of planets
VENUS GRAVITY: A HIGH-RESOLUTION MAP
R. D. Reasenberg (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139), Z. M. Goldberg, P. E. MacNeil, and I. I. Shapiro
The Doppler data from the radio tracking of the Pioneer Venus Orbiter (PVO) have been used in a two-stage analysis to develop a high-resolution map of the gravitational potential of Venus, represented by a central mass and a surface mass density. The two-stage procedure invokes a Kalman filter-smoother to determine the orbit of the spacecraft, and a stabilized linear inverter to estimate the surface mass density. The resultant gravity map is highly correlated with the topographic map derived from the PVO Radar Altimeter data. However, the magnitudes of the gravity variations are smaller than would be expected if the topography were uncompensated, indicating that at least partial compensation has taken place. (Gravity, Venus, isostasy)
J. Geophys. Res., Red, Paper 1B0747

6530 Gross properties of planets
THE F-RING OF SATURN
R. Smoluchowski (Departments of Astronomy and Physics, University of Texas, Austin, Texas 78712
One of the startling discoveries made by the Voyager Saturn flyby is the existence of a split and twisted F-ring located outside of the well known A-ring of this planet. It is proposed that the twist is the result of the action of Saturn's magnetic field on charged particles in the F-ring. A quantitative argument shows that small particles will be deflected away from a circular orbit maintained by the larger particles. The two "shepherding" satellites prevent the small particles from being lost entirely from the ring. (Saturn's rings, magnetic field, twisted orbits).
Geophys. Res. Lett., Paper 1L0727

6530 Gross properties of planets
THE MAGNETIC FIELD OF JUPITER: A GENERALIZED INVERSE APPROACH
J. E. P. Connerney (NASA/Goddard Space Flight Center, Laboratory for Extraterrestrial Physics, Planetary Magnetospheres Branch, Greenbelt, Maryland 20771)
The estimation of planetary magnetic fields from observations of the magnetic field gathered along a spacecraft flyby trajectory is examined with the aid of generalized inverse techniques, with application to the internal magnetic field of Jupiter. Model non-uniqueness resulting from the limited spatial extent of the observations and noise on the data is explored and quantitative estimates of the model parameter resolution are found. The presence of a substantial magnetic field of external origin due to the currents flowing in the Jovian magnetodisc is found to be an important source of error in estimates of the internal Jovian field, and new models explicitly incorporating these currents are proposed. New internal field models are derived using the vector helium magnetometer observations and the high field fluxgate observations of Pioneer 11, and knowledge of the external current system gained from the Pioneer 10 and Voyagers 1 and 2 encounters. (Jupiter, magnetodisc, magnetic field model, nonuniqueness).
J. Geophys. Res., Blue, Paper 1A0679

6540 Interior of moon
TIDAL DISSIPATION IN THE MOON
R. J. Cappallo, C. C. Counselman III, R. W. King, and I. I. Shapiro (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139)
Euler's equations of motion, modified to include elasticity and solid friction, were used to study the rotation of the moon. Two heuristic models for the anelasticity were considered: Q independent of frequency, and Q inversely proportional to the frequency of the strain oscillation. Parameters in each model were estimated by weighted-least-squares from nine years of lunar laser range observations. The root-mean-square of the postfit range residuals was 19 cm in each case. For a strain period of one month, the estimates of Q obtained with the two models were similar and surprisingly low: 23 ± 6.
J. Geophys. Res., Red, Paper 1B0782

6575 Surface of planets
CONTINENTAL RIFTING AND THE ORIGIN OF BETA REGIO, VENUS
George E. McGill[1], Susan J. Steenstrup[1], Colleen Barton[1], and Peter G. Ford[2]
[1]Department of Geology and Geography, University of Massachusetts, Amherst, Massachusetts 01003
[2]Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139
Topographic maps based on Pioneer Venus altimetry suggest that Beta Regio, an elevated feature centered at 27°N., 282°E., is analogous to domes associated with continental rift systems on Earth. This interpretation is consistent with the commonly quoted analogy between the East African rift system and the topography of the region from Beta Regio southward to Phoebe Regio. If Beta Regio is a dome, major structural uplift of the crust of Venus is implied, suggesting a more dynamic upper mantle than would be the case if Beta Regio were simply a large volcanic construct.
Geophys. Res. Lett., Paper 1L0867

6575 Surface of planets
EFFECTS OF LATERAL RESOLUTION ON THE IDENTIFICATION OF VOLCANOTECTONIC PROVINCES ON EARTH AND VENUS
Raymond E. Arvidson and Geoffrey F. Davies (Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, Missouri 63130)
Topographic data sets for the conterminous United States and the North Pacific have been degraded and displayed in the same manner as the Pioneer-Venus altimeter data for Venus. Results for the U.S. data show that the Cordillera orogenic zone would be seen as a broad swell with a height of 2 km and a wavelength of about 2500 km. Individual structural elements within the Cordillera are reduced to mild (height about 700 m; wavelength about 500 km) swells that are superimposed on the broad Cordillera rise. For the Pacific data, the Hawaiian swell, the E-W trending fractures in the Eastern Pacific, the increase in depth away from the East Pacific Rise, and most trenches, can still be discerned. The Venusian data do not show the integrated trench, transform, and ridge system evident in the degraded Pacific data. These features would be discernible in the degraded Pacific data even after correcting depths for: (a) the higher surface temperature on Venus; and (b) the lack of loading due to ocean water. Thus, a plate tectonic regime similar to Earth's does not appear to currently exist on Venus. Unfortunately, as shown by the degraded Cordillera data, the PV altimetry data are not of sufficient quality to discern whether or not the highlands of Venus preserve evidence for orogenic events related to an ancient epoch of plate tectonics. (topography, tectonics, Earth, Venus).
Geophys. Res. Lett., Paper 1L0865

6575 Surface of planets
SPECTRAL PROPERTIES (0.40 TO 0.75 MICRONS) OF SOILS EXPOSED AT THE VIKING 1 LANDING SITE
Edward A. Guinness (Dept. of Earth and Planetary Sciences, Washington University, St. Louis, Missouri 63130)
The bi-directional reflectance and photometric function was determined for seven patches of soil located near the Viking Lander 1 spacecraft. The soil photometric function is strongly backscattering and has a prominent opposition effect such that the ratio of reflectances at 1 degree and 10 degree phase angles averages 1.25, 1.24, and 1.19 in blue, green, and red wavelengths, respectively. The reflectance of the soil also exhibits a wavelength dependence as a function of phase angle. For instance, red/blue ratios can vary by up to 33% as the phase angle increases from 10 to 75 degrees. Estimates of soil reflectance at a 5 degree phase angle averaged over the blue and green passbands of the Viking Lander cameras are 0.11 and 0.17, respectively, while estimates of soil reflectance averaged over the red channel range from 0.30 to 0.39. There is little need to call upon mineralogical variations to explain the subtle color variations exposed at the landing sites. Rather, brightness and color variations within the soil can be correlated with particle size, with finer-grained soil being brighter and redder than coarser-grained soil. When compared to Earth-based reflectance data, the soil at the Viking 1 site is most like Martian bright areas. Such a result is consistent with the Lander soil being part of a globally homogenized soil unit. (Mars, photometry, spectral properties, Viking)
J. Geophys. Res., Red, Paper 1B0995

6590 Instruments and techniques
RADIOMETRIC PERFORMANCE OF THE VOYAGER CAMERAS
G.E. Danielson (M/S 170-25, California Institute of Technology, Pasadena, CA 91125) P.N. Kupferman, T.V. Johnson, L.A. Soderblom
The Voyager Imaging Experiment provided high quality data of Jupiter and the Galilean satellites with the two flyby trajectories in March and July of 1979. Moderately accurate radiometric measurements have been made using these data. This paper evaluates the radiometric results and describes the inflight and ground geometric and radiometric correction factors. The radiometric quantities of intensity, I and geometric albedo, I/F are derived and scaling factors for each of the filters are tabulated for correcting the "calibrated" data from the Image Processing Laboratory at JPL. In addition the key characteristics of both Voyager 1 and Voyager 2 cameras are tabulated. (Radiometry, photometry, Voyager Cameras).
J. Geophys. Res., Red, Paper 1B0900

6599 General or miscellaneous
THE ORIGIN OF MICROSCOPIC PLANETARY RING PARTICLES
J. F. Bates (Hanford Engineering Development Laboratory, P. O. Box 1970, W/A-65, Richland, Washington 99352)
The microscopic planetary ring particles around Jupiter are possibly the result of internal void formation and fracture of initially larger particles. The void formation is thought to be the result of high electron and proton fluences attained by the particles during their lifetimes in orbit. The constant irradiation produces defect species which coalesce to form voids, which provide fracture paths for the particles.
Geophys. Res. Lett., Paper 1L0901

Geotectonics

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Seismology

6905 Body Waves
THREE-DIMENSIONAL VELOCITY ANOMALIES IN THE UPPER CRUST NEAR SOCORRO, NEW MEXICO
R. M. Ward (Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, New Mexico, 87801)
J. W. Schlue and A. R. Sanford
262 P-wave arrival times associated with 30 local events obtained from a mobile array of up to eight short-period seismographs were used to determine hypocentral parameters and an accurate three-dimensional seismic velocity model for the Rio Grande rift zone near Socorro, New Mexico. The initial attempt to model these data resulted in a representative half-space velocity of [illegible] 0.02 (1 s.d.) km/sec. No azimuthal velocity variation was found that was significantly different from the half-space solution. The area was then subdivided at depth [illegible] into blocks one-tenth of a degree on a side. The resulting model showed that a block in the lower layer approximately [illegible] velocity of [illegible] km/sec less than the half-space velocity. Other blocks had smaller, but still significant, anomalies relative to the half-space velocity. The preferred explanation for the anomalous low velocity is that this area represents a site of magmatic intrusion into the upper crust (5-10 km deep). (3-D, velocity anomalies, upper crust, Socorro)
Geophys. Res. Lett., Paper 1L0599

6905 Body waves
ANOMALOUS SHEAR WAVE DELAYS AND SURFACE WAVE VELOCITIES AT YELLOWSTONE PARK, WYOMING
R.G. Daniel and D.M. Boore (Geophysics Dept., Stanford University; now at U.S. Geological Survey, 345 Middlefield Road, Mail Stop 77, Menlo Park CA 94025)
To investigate the effects of a geothermal area on the propagation of intermediate-period (1-30s) teleseismic body waves and surface waves, a specially designed portable seismograph system was operated in Yellowstone Caldera, Wyoming. Travel time residuals, relative to a station outside the caldera, of up to 2 s for compressional phases are in agreement with short-period residuals for P phases measured by other investigators. Travel-time delays for shear arrivals in the intermediate-period band range from 2 s to 9 s and decrease with increasing dT/dΔ. Measured Rayleigh wave phase velocities are extremely low, ranging from 3.2 km/s at 27 s period to 2.0 km/s at 7 s period; the estimated uncertainty associated with these values is 15 percent.
We propose a model for compressional and shear velocities and Poisson's ratio beneath the Yellowstone caldera which fits the teleseismic body and surface wave data; it consists of a highly anomalous crust with an average shear velocity of 3.0 km/s overlying an upper mantle with average velocity of 4.1 km/s. The high average value of Poisson's ratio in the crust (.34) suggests the presence of fluids there; Poisson's ratio in the mantle between 40 and approximately 200 km is more nearly normal (.29) than in the crust. A discrepancy between normal values of Poisson's ratio in the crust calculated from short-period data and high values calculated from teleseismic data can be resolved by postulating a viscoelastic crustal model with frequency-dependent shear velocity and attenuation.
(Shear waves, surface waves, magma, Yellowstone)
J. Geophys. Res., Red, Paper 1B0862

6905 Body waves
HIGH FREQUENCY Pn,Sn PHASES RECORDED BY OCEAN BOTTOM SEISMOMETERS ON THE COCOS PLATE
C. S. McCreery (Hawaii Institute of Geophysics, 2525 Correa Road, Honolulu, Hawaii 96822)
Data from ocean bottom seismometers located on the Cocos plate indicate that high-frequency Pn,Sn phases are generated by earthquakes along the subducting margin of that plate and are propagated across the plate. The Sn phase appears to be severely attenuated as it approaches the ridge crest. Estimates of Pn velocity are lower than previous estimates for western Pacific paths, which may indicate a relationship between Pn,Sn velocity and lithospheric age. High frequencies found in these phases suggest that Q for Pn,Sn propagation across the Cocos plate is similar to that for the western Pacific. (High-frequency Pn,Sn, Cocos plate).
Geophys. Res. Lett., Paper 1L0101

6930 Free oscillations (periods less than 12 hours)
STRUCTURE OF THE INNER CORE INFERRED FROM OBSERVATIONS OF ITS SPHEROIDAL SHEAR MODES
Guy Masters (Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, La Jolla, CA) and Freeman Gilbert
Spheroidal modes of elastic-gravitational oscillation that have an energy partition dominated by shear energy in the inner core are called core modes. Recordings from the IDA gravimeter network of an earthquake in the Tonga region on June 22, 1977 have provided the first unambiguous observations of core modes. They conclusively show that, at low frequencies, the inner core has a very high Q (about 3500). They also tightly constrain the ratio of the inner core radius to the mean shear velocity to be 115s with an uncertainty of [illegible]
Geophys. Res. Lett., Paper [illegible]

6940 Phenomena related to earthquake prediction
EXPERIMENTAL STUDIES OF THE [illegible] GEOCHEMICAL [illegible]
Jiang [illegible] California, Pasadena, [illegible]
The following [illegible] gas emission during [illegible] and rupture of rocks, [illegible] explosion sources, [illegible] experimental [illegible] physico-chemical processes [illegible] events. From these studies, [illegible] have been drawn:
(1) Long-term [illegible] appear to be related to the [illegible] deformation of rocks under stress leading prior to a seismic event. [illegible] to be related [illegible] and spike-like anomalies [illegible] shear displacement before an earthquake.
(2) Anomalous changes in chemical composition of groundwater and the escape of gases from the ground appear to result from rock fracturing which opens up pathways for the upward migration of water from deep, confined aquifers, and for the upward migration of gases from the deeper crust.
(3) Chemical reactions induced by increasing stress in the epicentral region may result in the anomalous changes in chemical composition of groundwater observed before some large earthquakes. (Earthquake prediction, radon monitoring, geochemical monitoring).
Geophys. Res. Lett., Paper 1L0510

6940 Phenomena related to earthquake prediction
A SEARCH FOR CO-VARIANCE AMONG SEISMICITY, GROUNDWATER CHEMISTRY, AND GROUNDWATER RADON IN SOUTHERN CALIFORNIA
D. E. Hammond, T. L. Teng, L. Miller and G. Baraguchi (Department of Geological Sciences, University of Southern California, Los Angeles, California 90007)
Several wells and springs near active faults in southern California have been monitored for the concentration of Rn, Na$^+$, K$^+$, Mg^{2+}, and Cl$^-$ for periods of up to 24 months, in an effort to see if any of these constituents show variations which may be related to seismic activity or environmental phenomena. A few of these sites have shown significant fluctuations.
One site in the San Gabriel Mountains has shown relatively high radon in the summer and low radon in the winter, apparently following the annual precipitation cycle. However, this site showed no corresponding change in its chemistry. A second site near Wrightwood, California has shown an annual cycle in its chemical composition, but shows no change in radon. Ten days prior to the Big Bear earthquake (M = 4.9), 45 km to the east, one sample from this site showed a 50% increase in radon, but no change in chemistry. A third site, 20 km north of the Malibu earthquake (M = 5.0) showed radon variation ranging from 0.4 to 4 times the normal concentration for two months preceding and two months following the event. The chemistry at this site did not change.
Within this study area, radon appears to exhibit anomalous variations within several tens of kilometers of impending earthquakes. The mechanism creating these signals has not been elucidated, but does not influence the composition of important ionic constituents. Groundwater radon concentrations may also reflect variations in precipitation but do not appear to reflect variations in atmospheric pressure. Data from cold springs are consistent with a model in which ionic constituents are controlled by reactions in the soil zone and radon concentrations are controlled by flow rates in the aquifer.
Geophys. Res. Lett., Paper 1L0552

6940 Phenomena related to earthquake prediction
PRELIMINARY SPECTRAL ANALYSIS OF NEAR-REAL-TIME RADON DATA
M.H. Mendenhall (W.K. Kellogg Rad. Lab., Caltech, Pasadena, CA 91125) M.H. Shapiro, J.D. Melvin, and T.A. Tombrello
Fast Fourier analysis of the near-real-time radon data collected since 1977 by the Caltech automated radon-thoron monitoring system has been carried out in order to determine if any characteristic frequency components are present that can be associated either with precursors to seismicity or with environmental factors. Preliminary results indicate that during "quiet" periods with low seismicity and no rainfall the spectral power is distributed as 1/f. Before four local earthquakes a departure from this 1/f behavior was observed at low frequency. During periods of heavy rainfall an increase in both low and high frequency power was observed. The spectral power of the large radon anomaly observed prior to the October 15, 1979 Imperial Valley earthquake was found to have a 1/f distribution but with power at all frequencies about four times greater than that of data from "quiet" periods. (Earthquake prediction, radon monitoring, spectral analysis).
Geophys. Res. Lett., Paper 1L0700

6940 Phenomena related to earthquake prediction
URANIUM CONCENTRATIONS AND $^{234}U/^{238}U$ ACTIVITY RATIOS IN FAULT-ASSOCIATED GROUNDWATER AS POSSIBLE EARTHQUAKE PRECURSORS
R.F. Finkel (Scripps Institution of Oceanography, S-002, La Jolla, California 92093)
In order to assess the utility of uranium isotopes as fluid phase earthquake precursors, uranium concentrations and $^{234}U/^{238}U$ activity ratios have been monitored on a monthly or bimonthly basis in water from 20 wells and springs associated with southern California fault zones. Uranium concentrations vary from 0.002 ppb at Indian Canyon Springs on the San Jacinto fault to 8.1 ppb at Lake Hughes well on the San Andreas fault in the Palmdale area. $^{234}U/^{238}U$ activity ratios vary from 0.88 at Agua Caliente Springs on the Elsinore fault to 5.4 at Niland Slab well on the San Andreas fault in the Imperial Valley. There was one large earthquake in the study area during 1979, the 15 October 1979 M=6.6 Imperial Valley earthquake. Correlated with this event, uranium concentrations varied by a factor of more than 40 and activity ratios by a factor of 3 at the Niland Slab site, about 70 km from the epicenter. At the other sites monitored, uranium concentrations varied in time, but with no apparent pattern, while uranium activity ratios remained essentially constant throughout the monitoring period. (Earthquake prediction, $^{234}U/^{238}U$ activity ratio, hydrology).
Geophys. Res. Lett., Paper [illegible]

6940 Phenomena related to earthquake prediction
LEVELING ARRAYS AS MULTICOMPONENT TILTMETERS: SLOW DEFORMATION IN THE NEW HEBRIDES ISLAND ARC
Michael Bevis (Department of Geological Sciences, Cornell University, Ithaca, NY 14853) and Bryan L. Isacks
Two benchmark arrays located on the islands of Santo and Efate in the New Hebrides Island Arc have been releveled 2 to 4 times per year during the past five years (1975-1980). Each array is thereby used as a multicomponent tiltmeter. The arrays are located within 35-50 km of the interplate thrust zone of this convergent plate boundary. Each array has an aperture of about 1 km and in addition contains small sub-arrays with apertures of about 70 m. This configuration leads to a resolving power (for tilt) of about one microradian. The most important result of this study is that, at the Devils Point array on Efate island, there has been a consistent tilting down of about five microradians in a direction sub-parallel to the strike of the arc. This tilting is clearly resolved by both the large array and by the small aperture sub-arrays. The observations are accounted for by a combination of planar tilting and random error consistent with the observed misclosures. Although tilting is clearly established at the Devils Point array, it is not possible at this stage to establish a unique cause for the observed tilt. Hypotheses consistent with the tectonic setting include interseismic strain accumulation associated with the earthquake cycle of loading and interplate boundary rupture, deformations near a transition between a creeping and a locked segment of the interplate boundary, and near surface deformations associated with magmatic activity and/or block movements also reflected in the pattern of faulting of the uplifted Pleistocene coral terraces. At the second array at [illegible] (Santo Island) no tilt trend clearly emerges from the noise level. However, two marginally significant tilt excursions precede in each case large earthquakes located several [illegible] north of the array. At the [illegible] array the ground noise (small wavelength elevation disturbances and benchmark instability) contributes to residuals almost as much as the measurement error, thereby degrading the threshold level for detection of tilt signals. The difference between the two arrays is not clearly established but seems to reflect an inherently larger level of short wavelength ground noise associated with geological properties of the [illegible] site.
J. Geophys. Res., Red, Paper [illegible]

6940 Phenomena related to earthquake prediction
[illegible] RADON ANOMALIES WITH [illegible] IN THE GREATER PALMDALE BULGE AREA
[illegible] University of Southern California, Los Angeles, California 90007
[illegible] radon anomalies [illegible] earthquakes [illegible] June 1979 [illegible] January 1, 1979 [illegible] A radon anomaly occurred at a nearby spring prior to the fall 1976 Palmdale swarm. The observed pattern is similar to pre-earthquake anomalies reported from Russia, China and Japan.
Geophys. Res. Lett., Paper [illegible]

6940 Phenomena related to earthquake prediction
[illegible]
[illegible] (Scripps Inst. of Oceanography, [illegible] La Jolla, CA 92093)
[illegible]

6910 Seismic sources (mechanism, magnitude, frequency spectrum, space and time distribution)
POSSIBLE EARTHQUAKE MIGRATION ALONG THE WESTERN EUROPEAN PLATE BOUNDARY
W.O. Limond* and H. Kara (Institut de Physique du Globe, Laboratoire de Geophysique Marine, 4 Avenue de Neptune, 94100 Saint-Maur-des-Fosses, France; *now at: British Petroleum Company, Britannic House, Moor Lane, London, EC2Y 9BU, Great Britain).
We have observed an apparent migration of seismic events along the North Atlantic Ridge from Jan Mayen Island to the Azores and eastwards, culminating in the large earthquake and associated aftershocks in the Gorringe Bank area in 1969. The migration velocity is about 80° of latitude in 9 to 12 months, about 7 to 10 km/day. Tests on normalized data show the migration to be statistically significant with a t-statistic equalling that for aftershocks, swarms, etc., occurring in an area. We believe this to be the first reported earthquake migration along a spreading ridge system, and one of the first with such high velocities. We hypothesize that the migration could involve creep migration along transform faults, since phenomena with velocities as high as this have involved creep along strike-slip faults. (Earthquake migration, Western Europe, plate boundary, creep).
J. Geophys. Res., Red, Paper 1B0428

6930 Seismic sources
NEAR-FIELD SURFACE MOTIONS EXCITED BY RADIATION FROM A SLIP-ZONE OF ARBITRARY SHAPE
John G. Harris (Theoretical and Applied Mechanics, University of Illinois, Urbana, Illinois 61801), J. D. Achenbach (Technological Institute, Northwestern University, Evanston, Illinois, 60201)
A ray method is used to calculate the near-field ground acceleration excited by sliding on a fault plane. The sliding action is modeled by a propagating Mode-II crack. The crack is planar and it has an edge of arbitrary but smooth curvature. Attention is focused upon the case in which the expanding crack abruptly changes its rate of growth to a slower one. This change in propagation speed causes a burst of wave motion to be emitted. The interaction of the high-frequency (or wavefront) part of the emitted acceleration pulse with the free surface is studied. The near-field, where body waves dominate the wave motion at the surface, is considered in some detail. (slip-zone, ray method, surface motion, near-field).
J. Geophys. Res., Red, Paper 1B0967

6930 Seismic sources
THE BERMUDA EARTHQUAKE OF MARCH 24, 1978: A SIGNIFICANT OCEANIC INTRAPLATE EVENT
G. S. Stewart, (Seismological Laboratory, California Institute of Technology, Pasadena, California 91125) D. V. Helmberger
The Bermuda earthquake (M = 6) occurred near the westerly extension of the Kane Fracture Zone roughly 370 km southwest of the Island of Bermuda. It is one of the largest oceanic intraplate earthquakes to occur off the eastern coast of North America. Because of its size and location, it has provided an excellent set of WWSSN body waves. They can be used to infer its depth and faulting parameters by waveform modeling techniques. The results indicate a north-northwest striking thrust mechanism (strike = N 20°W, dip = 42°NE, rake = 90°) with the hypocenter located at a depth of 11 km, which for an oceanic crust places it predominantly in the mantle. The event had a seismic moment of 3.4×10^{24} dyne-cm and its time history was modeled with a symmetric trapezoidal time function 3 seconds in duration. The north-northwest strike of the event is in good agreement with the bathymetry of the area, the epicenter being close to the southwestern edge of the Bermuda Rise. The strike of the event is also close to that of the inferred extensions of the present ridge fracture zones in the region. The presence of such fracture zones is indicative of local weak zones in the lithosphere. The Bermuda earthquake most likely is associated with one of these zones of weakness and is the result of the application of present day stress imposed on the region by the North American plate in the direction of its absolute motion. This is an important event in terms of understanding and estimating seismic hazard on the eastern seaboard of North America. (Bermuda, intraplate, earthquake, source parameters, oceanic, eastern U.S. seismicity, eastern North American seismicity).
J. Geophys. Res., Red, Paper 1B0745

6950 Seismic sources (mechanism, magnitude, frequency spectrum, space and time distribution)
THE RELATIONSHIP BETWEEN MICROSEISMICITY AND HIGH PORE PRESSURES DURING HYDRAULIC STIMULATION EXPERIMENTS IN LOW PERMEABILITY GRANITIC ROCKS
Chris Pearson (Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, New Mexico 87545)
Several hundred microearthquakes with local magnitudes ranging between -4 and -2 were recorded during hydraulic stimulation experiments at the Hot Dry Rock Demonstration Site, Fenton Hill, New Mexico. These events are probably caused by shear failure induced by high pore fluid pressures. Since the event locations seem to cluster in a narrow band near the hydraulic fracture, we were able to use microseismic techniques to locate the hydraulic fracture and monitor its growth. We calculate the minimum pore pressure increase necessary to induce rock failure using a simple model of slippage on preexisting fractures. By comparing a pore pressure distribution, calculated using a one-dimensional diffusion model with the distribution of event foci, we demonstrate that high pore pressures are a probable cause for these microearthquakes.
Stress drops for these microearthquakes, calculated from spectral parameters, increased by a factor of three during the course of the experiment. The stress drop increase correlates with a migration of seismic activity away from the injection wellbore, which suggests relatively low in situ shear stresses near the wellbore caused by strain release in this region during previous pressurizations. (Microearthquakes, source theory, hydraulic fracturing).
J. Geophys. Res., Red, Paper 1B0485

6950 Seismic sources
DEEP VOLCANIC TREMORS AND MAGMA ASCENT MECHANISM UNDER KILAUEA, HAWAII
K. Aki (Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139) and R. Koyanagi
Deep harmonic tremor originating at depths around 40 km under Kilauea was studied using records accumulated since 1962 at the Hawaii Volcano Observatory of the U.S. Geological Survey. The deep source of the tremor was determined by onset times and confirmed by the relative amplitude across the island-wide network of seismometers. The period of tremor was conclusively shown to be determined by the source effect and not by the path or station site effect because the period would change considerably in time but maintained uniformity across the seismic net during the tremor episode. The tremor appeared to be primarily composed of P waves. We interpret the observed period and amplitude in terms of the stationary crack model of Aki et al. (1977) and find that the seismic moment rates for deep tremors are considerably larger than those for shallow tremors suggesting more vigorous transport for the former. We propose a kinematic source model which may be more appropriate for deep tremor. According to this model, a measurable quantity called "reduced displacement" is directly proportional to the rate of magma flow.
A systematic search for deep tremor episodes was made for the period from 1962 through 1979, and the amplitude, period, and duration of the tremor was tabulated. We then constructed a cumulative reduced-displacement plot over the 18-year period. The result shows a generally steady increase which does not seem to be significantly affected by major eruptions and large earthquakes near the surface. The total magma flow estimated from the reduced displacement is, however, one order of magnitude smaller than that estimated by Swanson (1972). It may be that most channels transport magma aseismically, and only those with strong barriers generate tremor.
J. Geophys. Res., Red, Paper 1B0667

6970 Structure of the crust and upper mantle
THE P-WAVE VELOCITY OF THE UPPERMOST MANTLE OF THE RIO GRANDE RIFT REGION OF NORTH CENTRAL NEW MEXICO
James W. Murdock and Lawrence H. Jaksha (U. S. Geological Survey, Albuquerque Seismological Laboratory, Albuquerque, New Mexico 87115)
A network of seismograph stations has operated in north-central New Mexico since 1975. The network is approximately 200 by 300 km in size and encompasses the Rio Grande rift there. Several seismic-refraction experiments have been reported in the literature for the region of the network and adjacent areas. Because all of the seismic-refraction lines are unreversed, Pn velocities reported were mainly of the inverse travel-time slope for the direction of the corresponding line. The values of the inverse slope for those studies range from 7.6 to 8.2 km/sec.
The purpose of our study is to estimate the P-wave velocity of the uppermost mantle by using the time-term method. First, we timed the Pn waves of strong signals from five explosions and eight shallow earthquakes recorded by the network. The main data set, which contains 87 time-distance pairs, was processed by using the time-term method. The Pn velocity estimated by this method is 8.0 ± 0.1 km/sec. To corroborate this estimate, we then processed ten subsets of the main data set in the same way. Almost all of the solutions show velocities of 7.9-8.1 km/sec, in agreement with the velocity determined for the main data set. The station time terms of the main data set also are substantiated and they suggest that the base of the crust dips northward by a few degrees in the region of the survey. The smallest value reported by other investigators for the inverse slope (7.6 km/sec) appears to be related to the dip.
The normal P-wave velocity of the uppermost mantle of north-central New Mexico places restrictions on the thermal models of the rift. For instance, the results exclude the likelihood of a wide zone of asthenosphere at the base of the crust beneath the rift, but they do not exclude a narrow such zone.
J. Geophys. Res., Red, Paper 1B0710

6970 Structure of the crust and upper mantle
SIMULTANEOUS INVERSION FOR HYPOCENTERS AND LATERAL VELOCITY VARIATIONS: AN ITERATIVE SOLUTION WITH A LAYERED MODEL
B. V. Hawley, G. Zandt, and R. B. Smith (Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112)
An iterative inversion technique has been developed that uses the direct P- and S-wave arrival times from local earthquakes to compute simultaneously a three-dimensional velocity structure and relocated hypocenters. Crustal structure is modeled by subdividing flat layers into rectangular blocks. An interpolation function is used to smoothly vary velocities between blocks, allowing ray trace calculations of travel-times in a three-dimensional medium. Tests using synthetic data from known models show that solutions are reasonably independent of block size and spatial distribution, but sensitive to the choice of layer thicknesses. Application of the technique to observed earthquake data from north-central Utah shows the following: (1) lateral velocity variations in the crust as large as 7% occur over 30 km distances; (2) earthquake epicenters computed with the three-dimensional velocity structure were shifted an average of 3.0 km from locations determined assuming homogeneous flat layered models; and (3) the laterally varying velocity structure correlates with anomalous variations in the local gravity and aeromagnetic fields suggesting that the new velocity information can be valuable in acquiring a better understanding of crustal structure.
J. Geophys. Res., Red, Paper 1B0784

6970 Structure of the crust and upper mantle
COMPRESSIONAL-WAVE VELOCITY STRUCTURE OF THE UPPER 350 KM UNDER THE EASTERN SNAKE RIVER PLAIN NEAR REXBURG, IDAHO
John R. Evans (U.S. Geological Survey, Menlo Park, CA. 94025)
Relative travel-time residuals for teleseismic P and PKIKP are used to determine the compressional-velocity structure under the eastern Snake River Plain at Rexburg, Idaho. Damped-least-squares inversion of travel-time residuals (modified from the method of Aki) indicates a large body of 3.5±2.5% relative low-velocity material centered under the north west edge of the Snake River Plain. Less well resolved are two relative high-velocity bodies, one deep under the Idaho-Wyoming border, the other 300 km below the Idaho batholith. Comparison with similar velocity mappings of the Yellowstone region indicates that the Snake River Plain low-velocity anomaly is an aged extension of the low-velocity body under the Yellowstone caldera. The upper half of the body has vanished in the eastern Snake River Plain and the lower half is less anomalous than at Yellowstone. The strong dependence of mantle velocity structure on position under the Yellowstone-Snake River Plain volcanic system indicates loss of heat to the surface primarily by advective (heat movement by mass movement) mechanisms, not by conduction. No discrimination between propagating rift and upper mantle heat anomaly models of this northeast progressing volcanic system is possible because velocity structures associated with these hot spot models have not been predicted quantitatively. Upper mantle heat anomaly models (thermal plumes, chemical plumes, gravity anchors) explain the observed structure with fewer ad hoc assumptions, but propagating rift models cannot be eliminated. (Snake River Plain, Structure, Hot Spots, P-delays).
J. Geophys. Res., Red, Paper 1B0780

6970 Structure of the crust and upper mantle
SEISMIC REFLECTIONS FROM THE BASAL CONTACTS OF BATHOLITHS
Heloise B. Lynn, Laura D. Hale, George A. Thompson (Dept. of Geophysics, Stanford University, Stanford, CA 94305)
Although seismic reflection data in batholithic terranes are scarce, datasets available to us from three different regions show surprising similarities. All three profiles, one across Precambrian rocks in Texas, and two across Mesozoic batholiths in California and Nevada, show strong subhorizontal reflections at depths of 6-10 km. These reflections are interpreted to originate from the base of the batholiths, and indicate that these batholiths are tabular in shape. The large amplitude of the reflections requires a marked contrast in acoustic impedance (product of velocity and density) between the batholith and the underlying rocks. Two of the profiles show reflective zones having appreciable thicknesses (0.5-2.5 km), while the third profile shows a single continuous reflection. The four most favored candidates for sub-batholithic reflections are: 1) underplated gabbro, 2) cumulate layers, 3) migmatites, and 4) thrust faults. Cumulate layering is the preferred interpretation where reflectors constitute a thick package and are laminated in appearance. (Batholiths, seismic reflections, cumulates)
J. Geophys. Res., Red, Paper 1B0709

6970 Structure of the crust and upper mantle
VELOCITY-DENSITY PROPERTIES OF THE LITHOSPHERE FROM THREE-DIMENSIONAL MODELING AT THE GEYSERS-CLEAR LAKE REGION, CALIFORNIA
D. H. Oppenheimer and K. D. Herkenhoff (U.S. Geological Survey, 345 Middlefield Road, MS 77, Menlo Park, CA 94025)
The analysis of traveltime delays from 94 teleseisms recorded at The Geysers-Clear Lake, California region reveals a broad area of delay centered at Mount Hannah and encompassing The Geysers geothermal field. A three-dimensional velocity inversion of the delays indicates that the source of the delays is a low-velocity body largely within the top 30 km of the lithosphere. Velocity decreases of as much as 20% are observed in the top 15 km near Mount Hannah and diminish with depth. No significant velocity fluctuations are observed below 60 km. The block model of velocity perturbations resulting from the teleseismic residual inversion is used to predict the observed Bouguer gravity field by solving for the relation between velocity and density perturbation. Comparison between the predicted gravity and observed gravity indicates that the same body responsible for the teleseismic delays accounts for the long wavelength 30 mgal Bouguer gravity minima at Mount Hannah. The results of the velocity-density modeling suggest that the material beneath Mount Hannah and The Geysers may be partially melted and somewhat more silicic than the surrounding medium. (Teleseismic P delay, The Geysers, geothermal, gravity).
J. Geophys. Res., Red, Paper 1B0[illegible]

6970 Structure of the crust and upper mantle
GEOPHYSICAL CONSTRAINTS ON PARTIAL MELT IN THE UPPER MANTLE
T.J. Shankland (Los Alamos National Laboratory, Geophysics Group, Los Alamos, NM 87545), R. J. O'Connell, and H. S. Waff
This paper addresses the conditions under which partial melt can exist in the mantle in order to be observed as a geophysical "anomaly." Typical observed anomalies are: high electrical conductivity of order 0.1 S/m or greater, velocity decreases of 7-10%, seismic Q's less than 100, and a frequency band for seismic effects in the region near 1 Hz. Existing theories of electrical conduction in partial melts and of frequency-dependent seismic properties together with recent measurements of melt electrical conductivity, viscosity, and partial melt texture can be used to establish requirements for melt to be observed by geophysical methods. From electrical anomalies, mainly sensitive to melt volume and its interconnection, one can require a minimum melt fraction of several percent at temperatures close to the solidus (1150-1300°C). However, seismic models demand only a small volume in very flattened shapes (aspect ratio ~0.001, melt fraction ~0.1%).
Further, if melt configuration permits seismic dissipation in bulk, (i.e., there exist flattened voids intersecting more or less equant voids, then it is possible to infer melt fractions for elastic anomalies that are consistent with the several percent required for electrical anomalies. Observed equilibrium textures of partly melted peridotite together with inferred melt-solid surface energies suggest that melt on a grain-size scale in a gravitational field segregates into a strongly anisotropic pattern. Thus, if partial melt causes mantle geophysical anomalies, it should exist in a variety of void shapes and probably of sizes. While the association of electrical and elastic anomalies with indications of reduced density, volcanism, and high heat flow make the hypothesis of partial melting an attractive explanation, the minimum physical requirement is for existence of relatively high temperature (partial melting, low velocity zone, high conductivity layer).
Rev. Geophys. Space Phys., Paper 1R0664

6970 Structure of the crust and upper mantle
LATERAL VARIATIONS OF HIGH-FREQUENCY SEISMIC WAVE PROPAGATION AT REGIONAL DISTANCES ACROSS THE TURKISH AND IRANIAN PLATEAUS
K. Kadinsky-Cade (Department of Geological Sciences, Cornell University, Ithaca, New York 14853), M. Barazangi, J. Oliver, and B. Isacks
In this study we investigate crustal and uppermost mantle physical properties that characterize some of the continental plateaus of the Middle East. This is done as part of a larger effort to map and compare high-frequency wave propagation at regional distances across the earth's continental plateaus. Thousands of short-period WWSSN seismograms recorded at stations located in the Middle East and produced by earthquakes with epicentral distances less than about 20° were examined visually in an effort to study lateral variations of high-frequency (0.5-2 Hz) seismic wave propagation across this area, particularly to the north of the zone of continental collision between the Africa-Arabian and Eurasian plates. Variations of frequencies and amplitudes of Sn and Lg relative to P are examined and mapped throughout the region, and this work is supplemented by a study of velocities of Pn, Sn, and Lg. Sn amplitude variations are very striking in this area. An important observation of this study is that Sn propagates efficiently beneath a major part of the Turkish and Iranian plateaus. Sn is strongly attenuated, however, in the northernmost portion of the plateaus south of the Black and Caspian Seas, and in an area between the two seas. These regions are characterized, in general, by active tectonism, including volcanism, faulting, and folding. However, this active tectonism is not restricted to the areas of high Sn attenuation, but appears to extend beneath other parts of the Iranian and Turkish plateaus.
Patterns of lateral variations in the propagation of Lg are not as consistent as those for Sn. Lg propagates efficiently across Turkey, Iran and adjacent regions, but the Lg waves that cross the Turkish and Iranian plateaus are weak and have relatively long predominant periods of about 2-5 seconds. The Lg phase is not observed when the path of propagation crosses the southern Caspian and the Black Seas, consistent with the evidence of oceanic-type crustal structure beneath these seas. Lg is also not observed from sub-crustal events located in the Hindu Kush region. The velocity of Pn beneath most of the plateau areas, and particularly in the regions of Sn attenuation, ranges between 8.0 and 8.2 km/sec. Velocities for Sn and Lg throughout the Middle East are about 4.5 and 3.4 km/sec, respectively. It is possible to interpret the efficient Sn propagation and the relatively normal uppermost mantle P and S velocities beneath a major part of the Turkish-Iranian plateau as indicating a partial underthrusting of the Arabian continental plate beneath the Iranian and Turkish continental blocks. Alternatively the mapped regions of efficient Sn propagation and high Sn attenuation may result from a differential cooling of a past thermal anomaly. In this case the isostatic compensation of the plateaus could be due to an anomalously hot uppermost mantle that developed behind the Mid-to-Upper Tertiary subduction zone(s) in this region and to a subsequent crustal shortening after the collision of the Arabian and Eurasian plates. Our results cannot uniquely confirm the validity of the above proposed models. (Wave propagation, continental plateaus, tectonics).
J. Geophys. Res., Red, Paper 1B0961

Social Sciences

7310 Economics
ESTIMATING THE COSTS IN LOST POWER OF ALTERNATIVE SNAKE-COLUMBIA BASIN MANAGEMENT POLICIES
R. J. Hanson (Numerical Mathematics Division 5642, Sandia National Laboratories, Albuquerque, NM 87185) and C. B. Millham
A 51-dam, 56-time-period simulation model of the Snake-Columbia river basins, is described. The model is then applied to a series of alternative basin-management scenarios constructed for environmental or political interest. In each case, the impact in terms of lost power of that scenario, as opposed to basin management for optimal power generation, is quantified economically using the standard concept of "replacement cost." Stream flow data is taken for the period July 1, 1928-June 20, 1932, years including a 44-month "critical period" of historical low flows. The economic consequences of the alternative scenarios were computed using the simulation model. Mention is also made of a heuristic look-ahead model called "PASO" that was developed during this project. Some technical detail of the implementation of both models is included. (simulation, optimization, critical period, power, Snake-Columbia, stream flow, economic evaluation, replacement cost)
Water Resour. Res., Paper 1W0523

7310 Economics
MULTIOBJECTIVE ANALYSIS OF IRRIGATION PLANNING IN RIVER BASIN DEVELOPMENT
S. Vedula (Department of Civil Engineering, Indian Institute of Science, Bangalore-560012, India) and P. Rogers
A river basin which is extensively developed in the downstream reaches and which has a high potential for development in the upper reaches is considered for irrigation planning. A four reservoir system is modeled on a monthly basis using a mathematical programming (L.P.) formulation to find optimum cropping patterns, subject to land, water and downstream release constraints. The model is applied to a river basin in India. Two objectives, maximizing net economic benefits and maximizing irrigated cropped area, considered in the model, are analysed in the context of multiobjective planning and the trade-offs are discussed.
Water Resour. Res., Paper 1W0582

7310 Economics
WATER REUSE PLANNING MODELS: EXTENSIONS AND APPLICATIONS
G. Ocanas (Protesa, Monterrey, N.L., Mexico) and L. W. Mays (Department of Civil Engineering, University of Texas, Austin, Texas 78712).
A water reuse planning model has been developed for determining the optimum allocation of water and reuse of wastewater on a regional basis for multi-period planning that minimizes the overall cost of water supply. Both water quantity and water quality parameters of various sources of flows are considered. Wastewater from all use sectors, along with fresh water, can be considered as candidate sources or origins of water. The model considers the capacity expansion of treatment facilities and allows for economies of scale in treatment and transportation through the use of nonlinear objective functions. Either the large scale generalized reduced gradient or the successive linear programming methods can be used to obtain solutions to the models. Both single period and multi-period models are applied to a region including San Antonio, Texas. The single period model was applied to planning scenarios for the years 1980, 2000, and 2030. The multi-period model was applied using a planning horizon consisting of three periods, 1980-2000, 2000-2030, and 2030-2060. Comparisons were made of the single period model applications and the multi-period applications. The solution of a sequence of single period problems does not correctly represent the dynamic nature of the systems.
Water Resour. Res., Paper 1W0950

Solar Physics, Astrophysics, and Astronomy

7510 Corona
KINETICS OF CORONAL HOLE EXPANSION
Pei, Lie-pu (High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO. and Department of Geophysics, Peking University, Peking, China).
Based on the assumption of the undamped propagation of Alfven waves between 2 and 5 $R_\odot$, the possible range of Alfven wave energy flux density at the base of a polar coronal hole has been deduced. It is concluded that extended heating above 2 $R_\odot$ is needed to maintain the temperature maximum near 2 $R_\odot$ and to supply energy for the formation of high-speed wind streams. The energy contribution of extended heating to high-speed wind streams might be greater than that of Alfven waves by direct momentum addition.
J. Geophys. Res., Blue, Paper 1A0826

7[illegible] Electromagnetic Radiation
THE SOLAR SPECTRAL IRRADIANCE 1200-3184A NEAR SOLAR MAXIMUM: 15 JULY 1980
G. H. Mount (Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309) and G. J. Rottman
Full-disk solar spectral irradiances near solar maximum were obtained in the spectral range 1200-3184A at a spectral resolution of approximately 1A from rocket observations above White Sands Missile Range, New Mexico, on July 15, 1980. Comparison with measurements made in 1979 and during solar minimum confirm a large increase at solar maximum in the irradiance near 1200A with no change within our measurement errors near 2000A. Irradiances in the range 1900-2100A are in excellent agreement with previous measurements, and those in the 2100-2500A range are lower than the Broadfoot results. We find agreement with previous values [illegible]-2900A, and then fall below those values [illegible]-3184A.
J. Geophys. Res., Blue, Paper 1A0764

7[illegible] Electromagnetic Radiation
ESCAPING NONTHERMAL CONTINUUM RADIATION
W. S. Kurth (Dept. of Physics & Astronomy, The University of Iowa, Iowa City, IA 52242), D. A. Gurnett, and R. R. Anderson
Observations by the ISEE 1 plasma wave receiver reveal heretofore unreported details of the nonthermal continuum radiation from the earth. In particular, the higher frequency escaping component shows temporal and spectral features which are quite different from those of the lower frequency trapped emission. The higher frequency component is often clearly separated in frequency from the trapped component and high resolution spectrograms show that the escaping radiation consists of numerous narrowband emissions which drift slowly in frequency with time. The higher frequency component also exhibits greater temporal and spatial variability in both amplitude and frequency although the temporal variations are still quite smooth when compared to the more intense and higher frequency auroral kilometric radiation. Evidence is presented which clearly shows a direct connection between these electrostatic emissions near the upper hybrid frequency and the escaping continuum radiation and strongly suggests the latter electromagnetic emission is generated through mode coupling with the upper hybrid waves.
The new ISEE observations of the escaping continuum radiation from the earth strongly suggest a close correspondence with the newly reported narrowband kilometric radiation from Jupiter. Both emissions are relatively narrowband and show slow variations in amplitude with time. In both cases, the narrowband radiation lies above the trapped continuum radiation and below the intense extraordinary mode emissions (auroral kilometric radiation at the earth and decametric radiation at Jupiter). Evidence from both planets suggest the radiation is generated by intense electrostatic waves near the upper hybrid resonance frequency in the vicinity of the plasmapause at the earth and at the outer edge of the Io plasma torus at Jupiter. (Continuum radiation).
J. Geophys. Res., Blue, Paper 1A0545

7[illegible] Electromagnetic radiation
EARLY MEASUREMENTS OF THE SOLAR SPECTRAL IRRADIANCE DURING SOLAR MINIMUM, 1972 to 1977
G. J. Rottman (Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309)
Results of five sounding rocket experiments conducted between December 1972 and March 1977, a period spanning solar minimum between cycles 20 and 21, provide full disc solar irradiance in the spectral range 120 to 190 nm. Although a single measurement gives only a snapshot of the sun and does not account for short-term (minutes to hours) or intermediate-term (weeks to months) variations, the average of the five yields a solar minimum reference spectrum with an absolute accuracy of ±20%, appropriate to understanding long-term (11 year) variations in solar irradiance. Irradiance measurements obtained during this time period by other investigators are compared with this reference spectrum. A table of irradiances for the strong emission lines with wavelengths between 120 and 190 nm is presented. (Solar irradiance, Lyman-α, upper atmosphere, photochemistry).
J. Geophys. Res., Blue, Paper 1A0634

7[illegible] Mechanics
THE RADIAL STRUCTURE OF SATURN'S RINGS
William R. Ward (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109)
[illegible] diffusion in a particulate Keplerian disk under the influence of a viscosity law, ν(σ), that decreases with surface density, σ, more steeply than σ^{-1} (i.e. d (νσ)/dσ < 0) will promote the breakdown of the system into an ensemble of thin rings. Possible application to Saturn's rings is considered.
Geophys. Res. Lett., Paper 1L0800

7740 Magnetic fields
THE INTERPLAY BETWEEN MAGNETIC FIELDS AND CONVECTION
N.O. Weiss (Department of Applied Mathematics and Theoretical Physics, University of Cambridge, England)
The interaction between magnetic fields and convection was first modelled by considering the effect of a solid rotor on an otherwise uniform magnetic field. This approach has subsequently been extended by considering convection in an electrically conducting Boussinesq fluid in the presence of an imposed magnetic field. Nonlinear solutions for two-dimensional magnetoconvection show both steady and oscillatory behaviour. The results of a series of numerical experiments at a fixed Rayleigh number of 10^5 are presented and contrasted with predictions based on linear theory.
J. Geophys. Res., Red, Paper 1A0831

Tectonophysics

8110 Convection Currents
PARAMETERIZED THERMAL CONVECTION IN A LAYERED REGION AND THE THERMAL HISTORY OF THE EARTH
D. McKenzie (Bullard Laboratories, Dept. of Earth Sciences, Madingley Rise, Madingley Road, Cambridge CB3 0EZ, England) and F. Richter
Parameterized convective schemes for constant viscosity fluids are used to investigate the influence of layering on the relationship between the rate of heat loss from and heat supply to a number of convecting layers of different viscosity and thicknesses. Simple analytic expressions are obtained which accurately predict the behaviour to a step decrease in the heat supply, and show that layering considerably increases the response time. The same arguments are applied to a planet consisting of spherical shells. They show that the response of the Earth's heat loss to the decay of radioactive elements depends strongly on whether mantle convection extends from the core to the surface. If it does so the surface heat flux is only about 50% greater than the heat generation rate. But if upper and lower mantle convection occurs in two separate shells, as seismological and geochemical arguments suggest, the response time is increased. The present surface heat flux is then principally controlled by the thermal structure of the Earth at the time it was formed. The best estimate of the present ratio of the heat loss to heat generation is about two, and this value is consistent with the behaviour of an earth model consisting of a two layered mantle overlying a core.
J. Geophys. Res., Red, Paper 1B0619

8110 Convection Currents
ON SOME CONSEQUENCES AND POSSIBLE CAUSES OF LAYERED MANTLE CONVECTION
Frank M. Richter (Department of the Geophysical Sciences, University of Chicago) and Dan P. McKenzie
Laboratory and numerical experiments are used to study convection confined to discrete layers. The laboratory experiments, which use the water content of a predominantly glycerine solution as a way of establishing "chemical" density variations, show that convection will remain confined to superimposed layers when the chemical density contrast between layers is greater than the density change associated with the greatest temperature difference within the convecting system. The numerical experiments show a double thermal boundary layer at the interface between layers, a feature that would result in an average temperature increase near 700 km depth of about 500°C in the mantle. If the lower mantle is isolated as suggested by recent geochemical models. The possible causes of a layered mantle convection system include major element chemistry variations, the combined effect of major element chemistry and a phase change or a phase change alone if it has sufficiently negative Clapeyron slope. (Layered mantle convection)
J. Geophys. Res., Red, Paper 1B0408

8130 Heat flow
A PLAUSIBLE TWO-DIMENSIONAL VERTICAL MODEL OF THE EAST MESA GEOTHERMAL FIELD, CALIFORNIA, U.S.A.
F.P. Goyal (Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720) and D.R. Kassoy
A two-dimensional conceptual model of the East Mesa Geothermal system is developed on the basis of existing geological, geophysical, geochemical, heat flux, and borehole logging data. Hot water rising in a set of faults is assumed to charge the reservoir, which is overlaid by a clay-rich cap. The temperature-depth distribution observed at the site implies that the liquid is convecting at a high Rayleigh number. In this approximation, liquid rises up the fault and spreads isothermally into the nearby sections of the reservoir. The cooling effect of the surface on the flow in the reservoir is confined to a thin layer adjacent to the cap-reservoir interface near the fault. This layer grows with the distance from the fault. Eventually, the entire depth of the reservoir is cooled by the surface. The mathematical model is based on the flow of liquid water in a saturated porous medium. Results are obtained for the velocities, pressures, and temperatures in the entire system consisting of fault zone, aquifer, and clay cap. Finally we compare the predicted surface heat flux to that measured at the site in shallow wells. It is concluded that the model represents a plausible description of fault zone controlled systems like that at East Mesa.
J. Geophys. Res., Red, Paper 1B0706

8130 Heat flow
OCEANS AND CONTINENTS: SIMILARITIES AND DIFFERENCES IN THE MECHANISMS OF HEAT LOSS
J. Sclater (Department of earth and Planetary Sciences, M.I.T., Cambridge, Mass., 02139, USA) B. Parsons, and C. Jaupart
The principal objective of this paper is to present a simple and self-consistent review of the basic physical processes controlling heat loss from the Earth. To accomplish this objective we give a short summary of the oceanic and continental data and compare and contrast the respective mechanisms of heat loss. In the oceans we concentrate on the effect of hydrothermal circulation and on the continents we consider in some detail a model relating surface heat flow to varying depth scales for the distribution of potassium, thorium and uranium. From this comparison we conclude that the range in possible geotherms at depths below 100 to 150 km under continents and oceans overlap and that the thermal structure beneath an old stable continent is indistinguishable from that beneath an ocean were it at equilibrium. Oceans and continents are part of the same thermal system. Both have an upper rigid mechanical layer where heat loss is by conduction and a lower thermal boundary layer where convection is dominant. The simple conductive definition of the plate thickness is an oversimplification.
The observed distribution of area versus age in the ocean allows us to investigate the dominant mechanism of heat loss which is plate creation. This distribution and an understanding of the heat flow through oceans and continents can be used to calculate the heat loss of the Earth. This heat loss is 10×10^{12} cal/s (4.2×10^{13} W) of which more than sixty percent results from the creation of oceanic plate.
The relation between area and age of the oceans is coupled to the ridge and subducting slab forces that contribute to the driving mechanism for plate motions. These forces are self-regulating and maintain the rate of plate generation required to achieve a balance between heat loss and heat generation. (Heat flow, thermal structure, area-age.)
J. Geophys. Res., Red, Paper 1B0829

8150 Plate tectonics
THE EFFECTS OF HOTSPOTS ON THE OCEANIC AGE-DEPTH RELATION
R. Heestand (Dept. of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08544) S.T. Crough
Hotspots located both midplate and on midocean ridges can bias the empirical age-depth relation. Ocean floor bathymetry for seafloor greater than 80 mybp in age has been previously used to determine if the oceanic lithosphere behaves as a cooling halfspace or as a cooling plate. However, large areas of the ocean basins do not fit a simple age-depth relation. Anomalously shallow swells, approximately 1000 km wide and 1 km high surround hotspots such as Iceland, the Azores, and the Cape Verde Islands. By sorting seafloor depth data by distance to the nearest hotspot track, we show that the along-isochron variation in depth in the North Atlantic correlates with distance from a hotspot track. Due to the absence in the North Atlantic of seafloor both old and far from hotspots, we compare depth versus age at constant distance and do not observe flattening of the age-depth relation in any distance range. The age-depth relation, depth(meters) = 2700 + 295 $t(my)^{1/2}$, derived for seafloor 1200 to 1800 km from a hotspot track represents our best estimate of the age-depth relation appropriate to seafloor unaffected by a hotspot track. In the North Atlantic the previously inferred flattening of the age-depth relation appears to be caused by the inclusion of hotspot swells. This implies that hotspots may be the primary means of heat transfer from the deeper mantle to the base of the lithosphere. (Hotspots, subsidence).
J. Geophys. Res., Red, Paper 1B0665

8150 Plate Tectonics
A MODEL FORMING THE TRANSVERSE RANGES OF CALIFORNIA BY SUBDUCTION OF THE MURRAY TRANSFORM
B. Keller (Department of Geological Sciences and the Marine Science Institute, University of California, Santa Barbara, California 93106)
The East Pacific Rise collided with western North America in the last 30 m.y. A model in which the preexisting transform geometry was preserved as the actively spreading ridge was subducted under the continent accounts for the gross features of tectonic geometry of the west coast including the mountain blocks and deep Neogene sediment basins of the Transverse Ranges. The present day geometry in this model has transform motion at the surface along the San Andreas Fault and parallel features with decoupling to the East along the old subduction interface.
Geophys. Res. Lett., Paper 1L0416

8150 Plate tectonics
IGNEOUS EVOLUTION OF HESS RISE: PETROLOGIC EVIDENCE FROM DSDP LEG 62
K. L. Windom (Dept. of Earth Sciences, Iowa State Univ., Ames, IA 50011) K. E. Seifert and T. L. Vallier
Igneous rock was recovered at three sites on Hess Rise, north-central Pacific Ocean, during DSDP Leg 62: tholeiitic basalt at Site 464 (northern Hess Rise), trachyte at Site 465, and rounded clasts of alkalic basalt at Site 466 (both on southern Hess Rise). The depths at which the igneous rocks from Sites 464 and 465 were recovered correspond to strong acoustic reflectors, whereas the clasts from Site 466 were recovered from within calcareous sediment. Although all the rocks are moderately to highly altered, petrographic and chemical studies, especially rare earth element determinations, provide data on the nature of these rocks.
Data from these studies, combined with geophysical models of the evolution of the Pacific plate during the Mesozoic, allow an interpretation of the formation of Hess Rise involving building of a volcanic platform by eruption of tholeiitic mid-oceanic ridge basalt caused by the breakup of a R-R-R-type triple junction during the middle Cretaceous. This period of platform building was accompanied by edifice building along the south edge of Hess Rise involving alkalic basalt and its differentiation products associated with a leaky transform fault. This interpretation agrees with proposed models for the [illegible] tholeiitic parts of other oceanic plateaus, but requires a different mechanism [illegible] associated with leaky transform fault [illegible] count for the alkalic rocks.
J. Geophys. Res., Red, Paper 1B0621

8150 Plate tectonics
SPATIAL DISTRIBUTION AND MECHANISMS OF EARTHQUAKES IN THE SOUTHERN NEW HEBRIDES ARC FROM A TEMPORARY LAND AND OCEAN BOTTOM SEISMIC NETWORK AND FROM WORLDWIDE OBSERVATIONS
E. Coudert (Department of Geological Sciences, Cornell University, Ithaca, NY 14853) B.L. Isacks, M. Barazangi, R. Louat, R. Cardwell, A. Chen, J. Dubois, G. Latham, and B. Pontoise.
In 1977 a wide-aperture seismic network of land and ocean bottom stations (OBS) was operated for six weeks in the southern New Hebrides island arc. Data on the spatial distribution and mechanisms of small events recorded by this local network were integrated with worldwide observations of moderate- to large-size New Hebrides earthquakes of the past 17 years to study the structure and deformational processes in the New Hebrides subduction zone. Surprisingly small differences (less than about 10 km) were found between the locations of shallow- and intermediate-depth earthquakes as located by the temporary local network and by the International Seismological Centre (ISC) using worldwide stations. Analysis of the P-wave travel-time data from the OBS station closest to the trench shows limited evidence for a high-velocity zone (about 5% higher than the surrounding mantle) associated with the descending plate. The thrust zone between the descending and upper plates is defined mainly by the spatial distribution and focal mechanisms of moderate- to large-size events and their aftershocks, but it is not very well defined by the spatial distribution of small size events located in this study. Shallow seismic activity located beneath the trench and beneath the interplate thrust zone indicates a lower limit of about 40 km for the thickness of the seismically active part of the descending plate beneath the thrust zone. Focal mechanisms of moderate- to large-size earthquakes located within the upper plate and geological observations on the islands suggest that the upper plate in the region of Erromango and Tanna is divided into a series of blocks that are differentially uplifted along mainly NW-SE striking faults. During the OBS experiment several shallow events were well-located beneath the Coriolis trough, a rift-like feature located to the east of the volcanic arc. Well-determined depths of these events are between 11 and 22 km. The well-located intermediate-depth events define a 20 km-thick Benioff zone that has a dip of about 70°. The spatial distribution of events within the descending slab is very strongly clustered in a persistent pattern that is seen in both the short-term sample of small events determined by the local network and the long-term sample of locations based on worldwide data. Several focal mechanisms of moderate- to large-size intermediate-depth events show components of lateral extension along the strike of the arc and some show components of lateral compression, both of which could be interpreted as the result of a lateral bending of the descending plate in the part of the southern New Hebrides arc where the trench begins to curve around to the east.
J. Geophys. Res., Red, Paper 1B0571

8150 Plate tectonics
CRUSTAL STRUCTURE OF THE SUNDA FOREARC REGION WEST OF CENTRAL SUMATRA FROM GRAVITY DATA
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Free-air gravity anomalies near Nias Island include a -100 mGal low centered 10-20 km landward of the trench axis and a +80 mGal high over the outer arc ridge, but also show a few large anomalies unrelated to topography. A -90 mGal low is found on the structural high between the Banyak Islands and Sumatra, north of Nias. An 80-mGal rise (at a gradient of 8 mGal/km) is modeled by a near-surface body of high-density material (oceanic crust?) 9 km wide and tens of km long. This slab may be exposed on the southwest coast of Nias, where ultramafic bodies have been mapped, and its northerly trend (compared with northwesterly bathymetric trends) may be related to other obliquely-trending structures near here, to a proposed strike-slip fault which crosses Nias, and/or to the basement high topped by the Batu Islands. A -30 mGal free-air low over the forearc basin can be modeled best if pre-Miocene melange or continental crust underlies the basin, and it seems unlikely that the basin can be underlain by a large thickness of oceanic crust. (Sunda Arc, forearc basin, gravity anomalies).
J. Geophys. Res., Red, Paper 1B0838

8150 Plate tectonics
ISOSTASY AND THE AMBIENT STATE OF STRESS IN THE OCEANIC LITHOSPHERE
F.A. Dahlen (Department of Geological and Geophysical Sciences, Princeton University, Princeton, N.J. 08544)
Two conditions are normally considered to be characteristic of the state of stress in a system in local isostatic equilibrium. The first is that the stress is hydrostatic below some depth, the level of compensation, and the second is that above that depth there are no vertical shear stresses. In the case of a planar two-dimensional mid-ocean ridge these two conditions suffice to determine the stress completely except for the normal component parallel to the ridge, but to determine that component an additional assumption is required. It is proposed here that an appropriate additional assumption is that, in unflexed regions where the stress is due only to the elevation of mid-ocean ridges, the deviatoric stress in the oceanic lithosphere is a minimum. The unique state of deviatoric stress consistent with this assumption is horizontally compressive in a direction perpendicular to the axes of mid-ocean ridges with a magnitude in old ocean basins of a few hundred bars, in agreement with oceanic intraplate earthquake mechanisms. At any given distance from the ridge, the stress is maximum at the seafloor and it decreases with depth at about the same rate as the cooling of the lithosphere, so that the entire thermal boundary layer may be regarded as acting to support the global square-root-of-age topography of the oceans.
J. Geophys. Res., Red, Paper 1B0637

8150 Plate Tectonics
VENEZUELA BASIN CRUSTAL STRUCTURE
T.H. Diebold (Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964) P.L. Stoffa, P. Buhl and M. Truchan
Velocity-depth profiles derived from six, two-ship Expanding Spread experiments, in combination with other geophysical data, define the characteristics of two distinct types of Venezuela Basin crust and the boundary between them. Each two-ship Common Midpoint reflection/refraction profile is automatically transformed into the tau-p plane, "picked" and interpreted to provide V(Z) functions with appropriate confidence bounds. The results, together with gravity, magnetic and near vertical incidence reflection data, reveal a 50,000 km² triangle of Venezuela Basin crust which resembles normal oceanic crust in a magnetic quiet zone. North and west of this triangle lies the previously defined thick, "Caribbean" crust having two distinct layers above the M-discontinuity. Acoustic basement there appears unusually smooth, due to extensive basaltic sills and flows which were cored at DSDP sites 150/153 [illegible] [illegible] depths to mantle are greater than normal. Interpretations of near vertical and wide angle reflection [illegible] that the [illegible] crustal thickness is due not only to the [illegible] of the flows but to the [illegible] being somewhat thicker than normal. The [illegible] between the two crustal areas has a [illegible] [illegible] parallels the [illegible] structural and magnetic lineations. This boundary coincides in position, though not in trend, with the previously defined "Central Venezuela Basin fault zone". Further study is required to determine whether this boundary is of tectonic origin or if it represents a change in style of crustal production.
J. Geophys. Res., Red, Paper 1B0925

8190 Instruments and techniques
GENERAL CHARACTERISTICS OF STRAIN RELAXATION: A NOTE ON SAMPLE PREPARATION FOR LARGE-SCALE TESTS
T. Engelder (Lamont-Doherty Geol. Obs. of Columbia U., Palisades, NY 10964)
Overcoring and large block tests indicate that intact rocks are disturbed upon removal from outcrops so that their laboratory properties are not the same as their in situ properties. The disturbance occurs during strain relaxation for which there are general characteristics as listed in this note.
Geophys. Res. Lett., Paper 1L0610

8199 General or miscellaneous
THE 1886 CHARLESTON, SOUTH CAROLINA EARTHQUAKE AND THE APPALACHIAN DETACHMENT
L. Seeber (Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964) and J. Armbruster
Several lines of evidence from new and existing data are consistent with an extended fault slip associated with the 1886 earthquake in South Carolina. Back-slip over a portion of the Appalachian detachment approximately corresponding to the Coastal Plain of South Carolina fits some of the data including coseismic and post-seismic strain indicators. A small seismic source for the August 31, 1886 main shock cannot be ruled out, and a large, but only partially seismic fault-slip is possible.
During this event intensities of MM ≥ VIII occurred over a wide area of the Coastal Plain and are not limited to the Charleston-Summerville area where the traditional small source for this earthquake is located. Near-source effects such as ground fissuring, liquefaction, changes in line-of-sight, foreshocks and aftershocks occurred over a wide area of the Coastal Plain and neighboring inner Piedmont, which we refer to as the meizoseismal area. This area is sharply bounded by the Savannah River towards the southwest and approximately by the North Carolina -South Carolina state border towards the northeast. These boundaries are not associated with any known structure transverse to the strike of the Appalachians.
During the 14 years prior to 1886 seismicity was concentrated around the meizoseismal area while the seismicity within that area was unusually low, suggesting a premonitory doughnut-like pattern. The intensity distribution in the far and near field of the 1886 event and of the great Indian detachment earthquakes, e.g. the 1905 M = 8 and the 1934 M = 8.3 events, are qualitatively and quantitatively similar. This is consistent with comparable source dimensions since well known intermediate magnitude earthquakes in India and in Eastern North America exhibit similar intensity patterns and indicate similar seismic attenuation in the two cratonic environments.
Several meters of coseismic (1886) northwest compressive strain near Summerville is indicated by buckling of rails. A large post-seismic normal displacement is suggested by releveling data (1935-1968) across the Brevard fault zone updip (northwest) of the presumed 1886 detachment slip. These strains are consistent with a southeastward slip of the detached crystalline sheet associated with the 1886 earthquake. Available data indicates that in the southern Appalachians the updip transition from maximum horizontal to least horizontal compressive stress in the dip direction (perpendicular to structural trends) occurs somewhere in the Piedmont, and may coincide with the steepest portion of the detachment.
The stress-field may also contain a time-dependent component. In the sediments of the Coastal Plain, orthogonal sets of subvertical clastic dikes oriented along and across the Appalachian strike direction suggest one or more interchange of the principal stress axes. We infer from coseismic dry fissuring and liquefaction that clastic dikes filled from above and from below were also generated during the 1886 event. Prehistoric clastic dikes along with other structures in the sediments may have been generated during prehistoric earthquakes similar to the 1886 event. Stress reversals corresponding to earthquake cycles may characterize the stress field within detached sheets or wedges that move primarily by great detachment earthquake ruptures.
J. Geophys. Res., Red, Paper 1B0783